New Scientist

WEEKLY 20 August 2022

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New Scientist

THE SECRET LANGUAGE OF REALITY

FLUSHING OUT DISEASE

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Learn how to be an archaeologist at Mycenae, Greece

Join us on a trip around famous ancient sites and hidden gems of Greece. Includes a three-day "behind the ropes" experience at Mycenae, one of the most important archaeological sites in the country, where you will be taught how to explore, map and excavate by resident archaeologists. You will be accompanied by Christofilis Maggidis, president of the Mycenaean Foundation. The seven-day trip starts on 23 September and costs £1995.

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Podcast

Weekly

The team discuss the US Inflation Reduction Act and what it will mean for climate mitigation. They also ask why thinking hard makes us so tired, and chat about the wonderful, acid-defying scarlet-sided pobblebonk frog.

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NASA/JPL-CALTECH

Tearing it up The Fornax Cluster is ripping apart dwarf galaxies

P TOMLINS/ALAMY

Amateur archaeologist Learn how to excavate at Mycenae, Greece

Video

A-tishoo!

Watch sea sponges "sneeze" in slow motion to get rid of the sand and pollutants they suck into their bodies. Taking up to 50 minutes to complete, sponge sneezes use contractions to propel unwanted substances out of their body in long, sticky strings of mucus. The expelled mucus may be an important food source for small crustaceans and other organisms.

youtube.com/newscientist

Newsletter

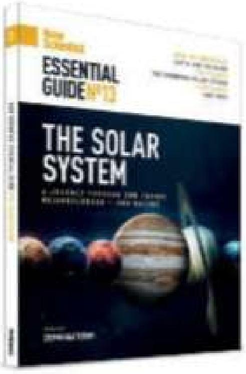
Launchpad

Reporter Leah Crane delves into the mysterious discovery that a nearby galaxy cluster, called the Fornax Cluster, appears to be ripping apart its dwarf galaxies. The ease with which they are tearing suggests that they don't contain any dark matter. If true, it may mean our understanding of the universe is wrong.

newscientist.com/launchpad

Podcast

> "Pobblebonk tadpoles live in a swampy environment that is almost as acidic as our stomach acid"



Essential guide

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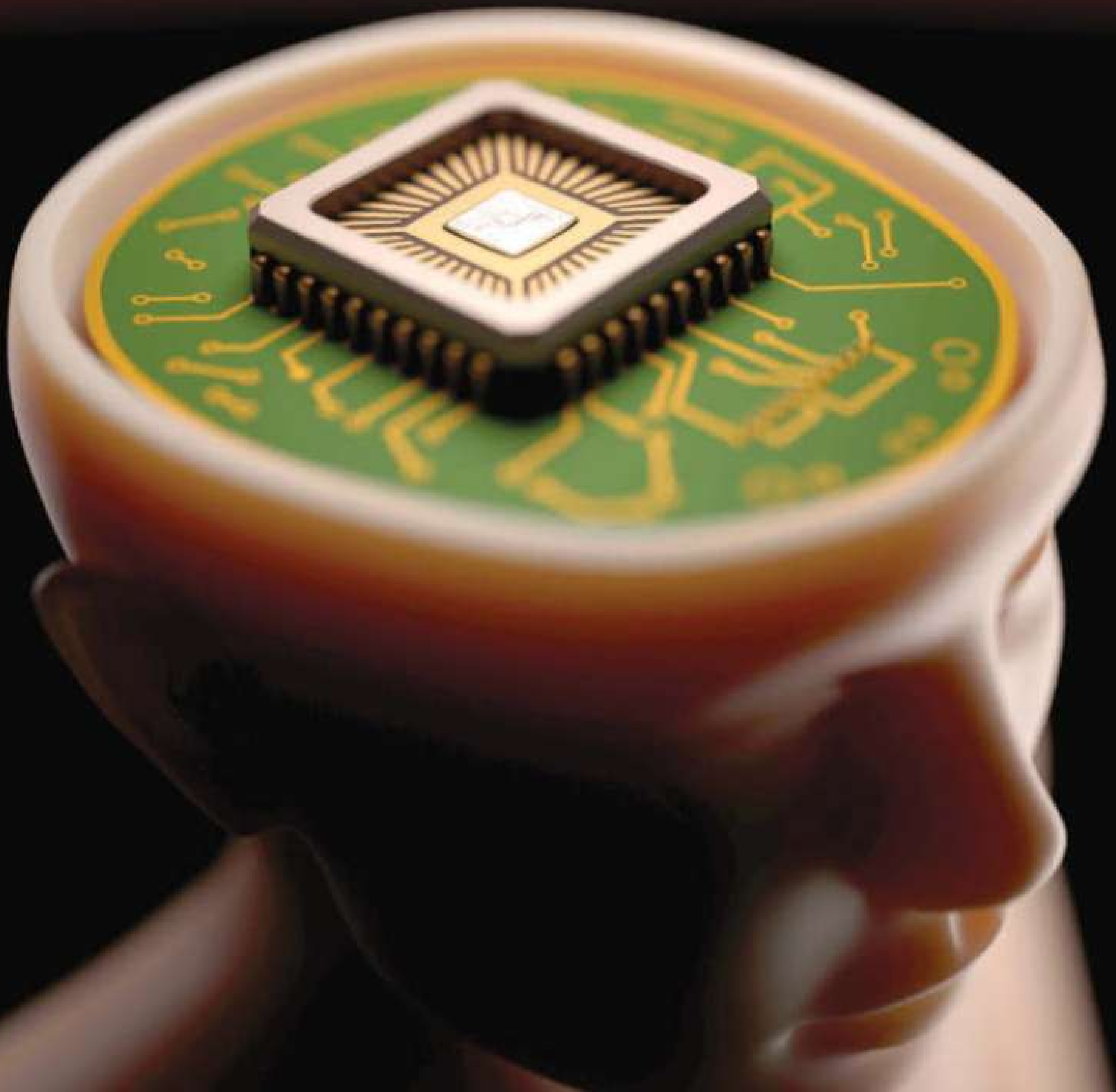

No time to waste

Sewer sludge is a valuable resource – but be careful how you use it

LAST week, health officials announced the detection of polio in New York City's sewage system, suggesting transmission of a virus that had all but disappeared globally. Earlier this year, a polio outbreak among children in London was similarly detected before any clinical cases were picked up. While such findings are worrisome, they also highlight the benefits of waste water surveillance for detecting and tackling outbreaks fast.

Using sewer sludge as a public health litmus test isn't a new idea. Since the mid 2000s, researchers have known that waste water can offer important insights into drug use, disease transmission and even diet. But it wasn't until the covid-19 pandemic that governments began to seriously tap into sewage's potential.

Trace amounts of genetic material from viruses, including covid-19, can be detected in waste well before people are symptomatic. This allows for earlier and cheaper detection. For these reasons, governments across the globe established waste water surveillance programmes to monitor covid-19 outbreaks, as we report in our feature on page 42.

> "People are wary of the method being used to track lifestyle factors and mental health"

Now, those same systems are being used to track, and potentially contain, the spread of other diseases. Earlier this month, Canadian officials announced plans to test sewage for monkeypox. Similar proposals have been floated in cities throughout the US.

But the wealth of information that can be gleaned from sewer slurry raises ethical questions too. Waste water surveillance takes disease monitoring out of the hands of individuals. Samples can't be traced to a single person, but, depending on where they are collected, can reveal the health of those living in a neighbourhood or even a particular building. Citizens are wary of the method being used to track lifestyle factors, genetic information or even mental health.

It is clear that these privacy concerns must be addressed with proper regulation. Only in doing so can we can tap into the revolutionary potential of waste water at a time when we need every disease surveillance tool in our arsenal. ■

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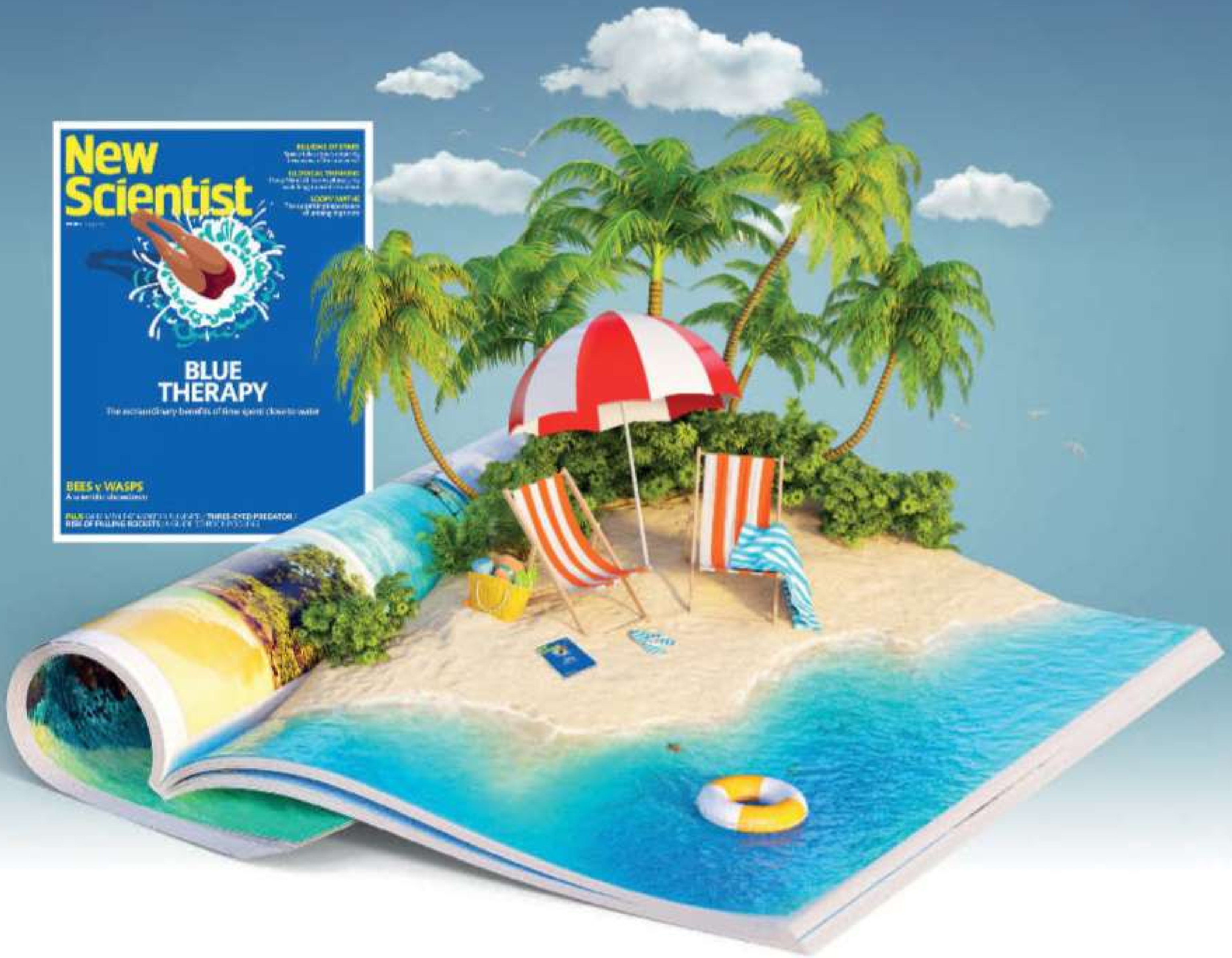

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Brain remodelling People with half their brain removed do well on tests **p10**

Long-haul flight Solar-powered drone stays airborne for two months **p11**

Mission to Mars Astronauts would get unsafe radiation doses **p14**

Finding our voice Humans lost part of voice box that other primates have **p16**

Ocean pollution Underwater robot identifies harmful garbage **p18**

A soldier near the Zaporizhzhia Nuclear Power Plant

REUTERS/ALEXANDER ERMOCHENKO

Ukraine war

Nuclear plant in danger

Ukrainian officials warn that shelling near the Zaporizhzhia Nuclear Power Plant could cause a radiation leak, reports **Matthew Sparkes**

FIGHTING at the largest nuclear power plant in Europe continues to present a real risk of a radiation leak, a nuclear scientist working in Ukraine has warned.

The Zaporizhzhia Nuclear Power Plant (ZNPP) near the Ukrainian city of Enerhodar has six nuclear reactors, all fuelled by uranium-235. The site has been controlled by Russian soldiers since March and reports from Ukrainian officials suggest that Russian troops are shelling parts of the site. These reports haven't been independently corroborated, but satellite images have revealed potential evidence of damage by bombing at the plant.

On 14 August, Ukraine's president Volodymyr Zelenskiy warned Russian forces that anyone shooting at or from the plant will become a target for "our intelligence agents, for our special services, for our army". He also claimed that Russian troops were using the plant as cover to fire on the cities of Nikopol and Marhanets.

In a joint statement issued on 12 August, 42 countries, including the US and the UK, urged Russian forces to withdraw from the site and allow normal operations at the plant to resume to ensure safety. The director general of the International Atomic Energy Agency, Rafael Mariano Grossi, has also called for military action near the plant to cease and stressed that there is an urgent need for an expert team to travel to the site to carry out safety checks.

One nuclear scientist working in Ukraine, who asked to remain anonymous, told *New Scientist* that the reactors at the ZNPP are built to a more modern design – known as VVER-1000 – than those at the Chernobyl nuclear power plant, with a better containment structure, but that there are still risks from nearby fighting.

> "The plant is designed to be protected from terrorist threats, but not from military fighting"

"Normally, the design of containment should resist an external impact like the crash of an airplane. The concrete shell of VVER-1000 containment is about 1.2 metres thick," he says. "However, the safety of a nuclear power plant is not only down to the containment of the reactor itself; it's also the work of auxiliary equipment that ensures the cooling of the reactor and spent fuel. We have to keep in mind that [a] loss of power caused the accident in Fukushima [in Japan in 2011]."

Aside from the reactor, there is also liquid and solid radioactive waste stored on site. If damaged during shelling, this could cause a radiation leak to the environment, the nuclear scientist says. "The plant is designed to be protected from terrorist threats, but not [from] military fighting. All should be done to avoid any chance of fighting, not only at the plant site, but in all the areas around," he says.

An update issued on Telegram by Energoatom, Ukraine's state-controlled energy company, said that as of 8am local time on 15 August, the ZNPP is operating safely, but that fighting is continuing. "Periodic shelling of the ZNPP by Russian troops with anti-aircraft missiles since last week has caused a serious risk to the safe operation of the plant," it said. "There are still risks of hydrogen leakage and sputtering of radioactive substances, and the risk of fire is high."

The agency said that auxiliary buildings at the site had been damaged and three radiation monitoring sensors around the site had been hit. It also claimed that a fire station outside the plant had been shelled, increasing the potential danger of fires. Reports last week suggested that one member of plant staff had received shrapnel wounds. ▮

Climate change

Worst drought in 500 years?

River flows across Europe are down by a third, exacerbating food and energy crises

Michael Le Page

EUROPE is experiencing what may be its worst drought in 500 years, with river flows down by around a third on average. The drought, which is likely to have been intensified by global warming, is having a serious effect on food production and river transport at a time when there is already a food crisis and soaring energy costs due to the Russian invasion of Ukraine.

In much of Europe, rainfall was lower than usual leading up to summer, and there has been no significant rainfall in many areas since. There have also been above-average temperatures and record-breaking heatwaves, with the UK hitting 40°C (104°F) for the first time. The result is parched soil and falling water levels in rivers, dams and lakes.

"What we see this summer is a compound event, when two or more climate hazards occur simultaneously or sequentially, in this case hydrological drought and heatwaves," says Dominic Royé at the University of Santiago de Compostela in Spain.

Royé has mapped how river levels in Europe compare with the 1980 to 2021 summer average. Overall, river flows are down 29 per cent, with some down 62 per cent. Only in a few places, such as northern Scandinavia, are river flows above normal.

It could be the worst drought in Europe in 500 years, Andrea Toreti of the European Commission's Joint Research Centre told a news conference on 9 August. "There were no other events in the past 500 [years] similar to the drought of 2018," he said. "But this year, I think, is worse."

A satellite image shows a dry western Europe on 9 August

SIMON PROUD/NCEO/RAL SPACE/NASA

Global warming is very likely to be partly to blame, making the heatwaves hotter than they would otherwise have been. Climate change has weakened the jet stream that brings Atlantic moisture to Europe, making severe droughts of this kind more likely, according to Peter Hoffmann at the Potsdam Institute for Climate Impact Research in Germany, reported *Associated Press*.

The drought is affecting food yields, energy production and wildlife (see "Dry rivers and stressed plants hit wildlife hard", right), among other things. The impact on crops varies, but rice production in Italy has been badly hit, with some farmers predicting losses of more than 60 per cent. Livestock farmers, meanwhile, are having to feed animals that would normally be grazing. All this means that food prices, which are already at record levels, are likely to rise further.

The drought is also making the energy crisis worse. Hydropower generation is down by a fifth across Europe and some nuclear plants have been forced to lower their outputs to ensure rivers aren't overheated by the cooling water the plants discharge.

Low water levels are affecting the transport of coal, oil and other goods down rivers like the Rhine, where barges have been forced to carry less than usual so they don't hit the riverbed. Water levels in parts of the Rhine could fall so low that barges stop operating altogether. ▮

Health

US government wants to create 'too-hot-to-work' rules

AS INTENSE heatwaves baked much of the US this summer, federal investigators made more heat-related inspections at workplaces than they carried out in the previous three years combined. The upswing reflects a new emphasis on protecting workers from extreme temperatures as federal plans for a national heat-safety standard go forward in a race to beat the heat.

According to data from the US Department of Labor, there were 344 fatalities and 22,660 injuries and illnesses from exposure to environmental heat in the workplace between 2011 and 2019. However, neither the federal government nor most US states have laws that require employers to take specific measures to protect workers from heat. The UK also lacks laws explicitly protecting workers from heat.

"Next to covid, this is the next big thing" for workplace safety, says Melanie Paul, an attorney at Jackson Lewis in Georgia.

In response to an executive order on "tackling the climate crisis" from the Biden administration last year, the Occupational Safety and Health Administration (OSHA) announced it would start developing a national heat-safety standard.

The rule could resemble a California law requiring employers to provide shade and water when the temperature tops 80°F (26.6°C), and paid breaks when temperatures top 95°F (35°C). However, it could take years to develop.

> "Most US states lack laws that require employers to take specific measures to protect workers from heat"

In the meantime, OSHA has started proactively inspecting workplaces when the heat index hits 80°F, focusing on at-risk industries such as agriculture and construction. Between April and late July, federal investigators with OSHA carried out 705 inspections in 45 states, according to data acquired by *New Scientist*. Between 2015 and 2020, OSHA conducted about 200 heat-related inspections each year. The uptick "shows that they really are putting their money where their mouth is", says Paul. ▮

James Dinneen

Ecology

Dry rivers and stressed plants hit wildlife hard

Adam Vaughan

FROM birds and butterflies to salmon and trout, England's extreme dry conditions are taking their toll on wildlife. Drought status was declared for eight areas of the country on 12 August after the driest July since 1935, and looks set to last; on 9 August, the UK's Centre for Ecology and Hydrology said rivers will be "exceptionally low" until October in central, eastern and southern England.

While millions of people are being affected, other species are facing life-threatening impacts as river levels fall, peatlands dry out and soils turn brick-like. Drought orders mean water companies will be able to take more water than usual from rivers, further squeezing the health of natural environments.

Some species are adapted to natural cycles of drought, with roughly half of freshwater species able to cope with such conditions, says Jeremy Biggs at the Freshwater Habitats Trust. However, England's wildlife still faces numerous threats from a dry summer, a lack of cool water and fires that can more easily spread in parched conditions.

The UK's Environment Agency has rescued and relocated fish from the river Teme in Shropshire and the Tarrant in Dorset, as well as other rivers. In some rivers where dissolved oxygen levels have become perilously low, it has deployed aeration equipment.

Insects are also being affected. Drought-stressed vegetation has stopped flowering, raising concerns over a once-widespread bee, the shrill carder bee, says Matt Shardlow at Buglife.

"Extended heatwaves and drought are having a devastating impact on UK wildlife, reducing the availability of water and food, and exacerbating the impacts of pollution from farming and sewage," says Kathryn Brown at The Wildlife Trusts. ▮

Analysis Water infrastructure

England faces a drier future

As climate change brings more frequent droughts, major investments are needed to prepare for water shortages, says **Adam Vaughan**

RICHARD BAKER / IN PICTURES VIA GETTY IMAGES

Parched grass in Greenwich Park, London, on 4 August

DROUGHTS in England are nothing new, despite its reputation as a rainy nation. But climate change is leading to hotter, drier summers like the current one, and summer rainfall in the country is expected to decline by roughly 15 per cent by the 2050s. This trend and the nation's growing population mean sticking-plaster solutions, such as the hosepipe bans now facing millions of people in England, aren't a long-term answer to water shortages.

The solutions fall into three buckets: new water supply, fixing leaking pipes and using water more efficiently. A 2018 report by the National Infrastructure Commission (NIC), which advises the UK government, found that each of the three approaches will contribute roughly a third of the 4 billion extra litres of capacity England will need per day in coming decades. The Environment Agency reached similar conclusions two years later.

Paul Hickey at the Regulators' Alliance for Progressing Infrastructure Development, a body set up in 2019 by three water regulators to advance big water infrastructure projects in England and Wales, says the current dry conditions reinforce the need to take action on all three fronts. "We know that climate change, the changing needs of society and increasing population will put pressure on water sources – and we can expect more frequent [dry] events, as we're experiencing."

On the supply front, the focus is on major new reservoirs to increase storage, as climate change is expected to bring warmer, wetter winters. Proposed ones include a scheme near Abingdon in Oxfordshire, two in East Anglia, one in south-east Lincolnshire and one in the Fens of eastern England.

4bn litres

Extra water supply England is projected to need per day

Another measure is improving water transfer from wetter parts of the UK to the driest parts in south-east England. Proposals include a pipeline from the Severn river to the Thames, as well as using England's longest canal, the Grand Union.

Many of these big infrastructure projects will go for consultation in November, with the intent to start building from 2025 onwards. Hickey says many projects will be elevated in the planning process to national decisions, so the UK's next prime minister will have to take "some political decisions" on approvals.

The cost will ultimately be borne by consumers via water bills. But the NIC suggests the cost of inaction would be more: £40 billion over 30 years for emergency responses including trucking water versus £21 billion for the investments needed.

Desalination plants, which turn seawater into fresh water by removing salt, are also likely to play a role in the future, says Hickey. Despite the dry conditions, the UK's only existing major desalination plant, run by Thames Water in east London, is offline until next year due to maintenance work.

Leaking pipes are a big issue too: 9 cubic metres leaked per kilometre per day on average last year.

Other efforts are being made to use water more efficiently. The UK government is expected to announce plans for mandatory water efficiency labels for products such as toilets and showers in coming weeks, and water meters are seen as vital: households with them use 24 per cent less water per day on average. Water firms need to educate consumers about the environmental impact of their water use too, says Hickey. "It's a really powerful way to get people to engage with this agenda," he says. ▮

Memory

People with half a brain recognise words and faces well

Jason Arunn Murugesu

ADULTS who had one half of their brain removed in childhood to treat seizures still recognise faces and words at a reasonably high level.

Marlene Behrmann at Carnegie Mellon University in Pittsburgh, Pennsylvania, and her colleagues wanted to find out how the loss of either brain hemisphere affects our ability to recognise words and faces – word recognition is generally processed in the brain's left hemisphere and face recognition in the right hemisphere.

The team tested 40 people who had the surgery as children for epileptic seizures. The participants were presented with faces with all colour and hair removed. These appeared on a screen for 750 milliseconds. After a 150ms gap, they saw another face for 150ms and were then asked whether the faces were the same.

Word recognition was tested in the same way using similar four-letter words, such as tack and tank. The 40 participants were also age and gender-matched with 58 people who had both hemispheres.

The team thought people with only their right hemisphere would perform better at face recognition, while those with just their left hemisphere were expected to score more highly at word recognition.

Instead, people who had either hemisphere removed had an average accuracy of 86 per cent across both tasks, compared with 96 per cent in the control group (medRxiv, doi.org/h77w). Accuracy like this doesn't occur when damage to brain regions involved in face or word recognition occurs in adulthood.

Daniel Mirman at the University of Edinburgh, UK, says the study suggests the childhood brain is very plastic. "If only one hemisphere's resources are available, then both behaviours will rely on that resource rather than splitting it between the two hemispheres." ▮

Astronomy

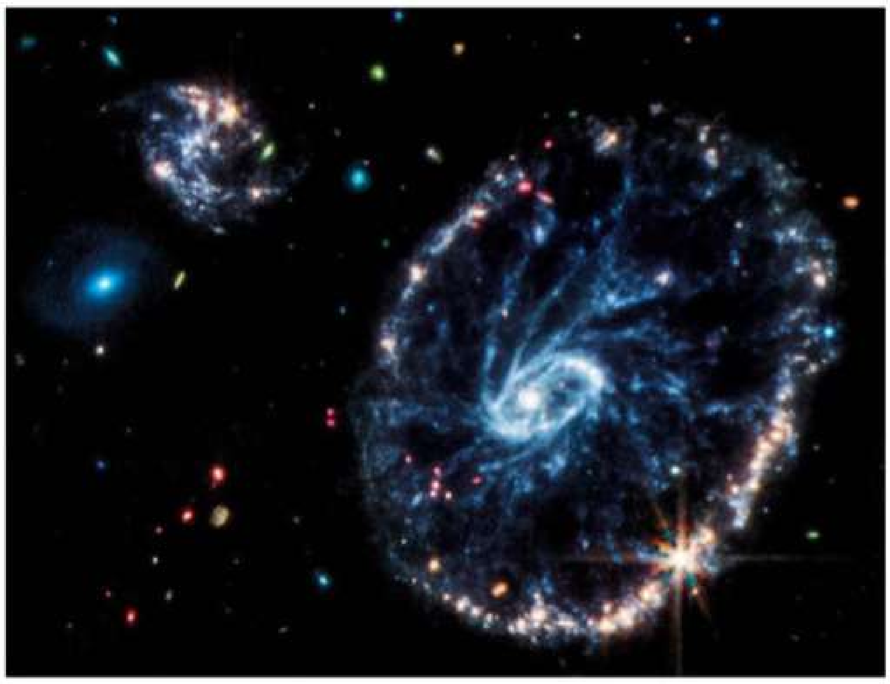
Faint galaxies may be closer than they appear with JWST

Leah Crane

THE James Webb Space Telescope (JWST) is performing better than expected, which might be a problem for some of the early results. An update to the telescope's data stream could mean that many galaxies spotted early on aren't as distant as they seem.

Raw data from JWST doesn't come as complete images. Astronomers have to process it to make it usable, which requires understanding the sensitivity of the telescope's scientific instruments. As JWST takes more readings, we get a better sense of that sensitivity. However, the performance of an infrared camera caused the telescope's operators to update its data-processing algorithms in July – well after the first images were released – and threw some astronomers into a tizzy.

"When the first images came out, it was a bit of an 'astronomers at Christmas' scenario with everyone diving in to see what they could find," said Nathan Adams at the University of Manchester, UK, in a statement. "What I think flew under the radar of a lot of astronomers was a part of that report mentions that NIRCam (one of the main cameras on the telescope) was overperforming in its reddest wavelengths."



A JWST image of the Cartwheel galaxy and several other galaxies

NASA, ESA, CSA, STSCI, WEBB ERO PRODUCTION TEAM

Astronomers use the colour of an object's light to measure its distance. The faster a galaxy is moving away from us, the redder it appears. Because of the expansion of the universe, this means that the redder a galaxy seems, the more distant it is, a phenomenon that astronomers use to measure distance.

> **"Some early science from JWST data may be incorrect, especially for the faintest galaxies"**

Adams and his colleagues reanalysed some early JWST data after the update and found that some galaxies are actually less red – and so less distant – than they initially appeared (arxiv.org/abs/2207.11217).

"It's potentially a very big deal," says Guido Roberts-Borsani at the University of California, Los Angeles. Some early science coming from JWST data may be incorrect, especially for the faintest galaxies, where distance and luminosity are determined with fewer data points than brighter galaxies. Some faint galaxies may be more than 10 times closer than we thought.

However, that doesn't apply to everything. "This whole clamour of 'oh my god, everything that everyone has written in the last few weeks is wrong, throw it out the window' is really not the case," says Rohan Naidu at the Harvard-Smithsonian Center for Astrophysics. "This is not unexpected, and many researchers made conservative choices in their work to account for it." For bright galaxies, the corrections that need to be made to researchers' calculations may not be all that extreme, he says.

It may even solve a mystery: JWST's first observations seemed to show far more extremely distant galaxies than expected based on models of galaxy evolution. This might be the reason why, said Adams. If those galaxies aren't so far away, the tension between theory and observation evaporates. "This helps with part of the tension, but doesn't completely solve it," says Roberts-Borsani. "There are still these bright monsters at high distances where we don't really expect them to be forming stars like crazy."

More JWST calibrations will come through in the coming months, but they are expected to be less severe, said Adams. For now, astronomers who analysed JWST data before this update are double-checking their conclusions. "Of course, in the long run, we're going to iron all this out," says Naidu. ▮

Technology

Record-breaking flight

A reconnaissance drone has remained in the air for more than two months

Matthew Sparkes

AN UNCREWED solar-powered aircraft has smashed its previous flight duration record by remaining aloft for more than 60 days – and it is still airborne.

The Zephyr S, built by Airbus in the UK, has photovoltaic solar panels on top of its wings that can power its electric motor and recharge its batteries so that it can fly throughout the day and night.

Designed for long-term reconnaissance missions, the Zephyr, pictured, has a wingspan of 25 metres and weighs less than 75 kilograms. The US Army is testing the aircraft above its Yuma Proving Ground in Arizona.

As of 15 August, the aircraft has travelled around 80,000 kilometres since taking off on 15 June, according to data provided to *New Scientist* by Plane Finder. The previous record duration for an uncrewed flight was just under 26 days, set by a Zephyr in 2018.

AIRBUS

Wildlife

Huge increase in saiga antelope population

SAIGA antelopes have rebounded after being hunted to the brink of extinction less than two decades ago and sustaining huge losses to disease in 2015. An estimated 1.3 million saiga now roam the steppe grasslands of Kazakhstan, a 30-fold increase from a population of less than 40,000 in 2005.

"I went [to the Kazakh steppe] in 2006 and we saw maybe seven saiga in a week," says Mark Day, who leads the Kazakh Steppe Conservation Programme at the Royal Society for the Protection of Birds (RSPB). "Now, all you hear is this mooing sound. You're surrounded by tens of thousands of saiga. It is an amazing transformation."

Millions of these antelopes (*Saiga tatarica*) once grazed alongside woolly mammoths and steppe bison throughout the Eurasian grasslands. But the collapse of the Soviet Union in the early 1990s led to widespread unchecked poaching of the goat-sized animals for meat and horns, and the population dwindled to tens of thousands.

Land protections and hunting bans gave saiga the space to reproduce, and by the mid-2010s, there were 250,000 antelopes on the Kazakh steppe. Then, the already fragile population was hit by a fatal bacterial pathogen that swept through half of the world's saiga within a few weeks.

While it was a serious blow to the species, hoofed mammals like antelopes can make astonishing rebounds from mass die-offs. Female saiga have multiple calves at once, and with no predators, their numbers have been skyrocketing since. An aerial drone survey done by the RSPB this past spring estimates there are now around 1,318,000 saiga on the steppe.

"This is possibly the largest increase in biomass for any kind of conservation recovery"

"This is possibly the largest increase in biomass for any kind of conservation recovery," says Day.

The government of Kazakhstan has reserved nearly 5 million hectares of the steppe ecosystem in the past 20 years – an area the size of Denmark – for wildlife like the saiga.

The animals' recovery has become part of the national identity of Kazakh people, according to Vera Voronova at the Association for the Conservation Biodiversity of Kazakhstan. "It's become a species that people are really proud of," she says.

Though saiga have been the poster child of Kazakh steppe restoration, their recovery is linked to the return of other species, like the ground-nesting steppe eagle. Because the eagles scavenge on meat, the abundance of saiga has meant more food for the birds. ▮

Corryn Wetzel

Nuclear physics

Fusion ignition confirmed

A 2021 experiment achieved the milestone of nuclear fusion ignition, but attempts to recreate it haven't been successful, reports **Karmela Padavic-Callaghan**

WE HAVE ignition. An analysis has confirmed that an experiment conducted in 2021 created a fusion reaction energetic enough to be self-sustaining, which brings fusion one step closer to being useful as a source of energy.

Known as ignition, this reaction took place on 8 August 2021 at the Lawrence Livermore National Laboratory's National Ignition Facility (NIF) in California, but NIF researchers haven't been able to reproduce the achievement since. They have spent the past year analysing the experimental conditions that resulted in ignition to determine how to repeat it.

In the experiment, 192 of the world's most energetic lasers hit a millimetre-sized capsule filled with hydrogen. This turned the capsule into a hot plasma that quickly collapsed into a tiny sphere about 18,000 times hotter than the surface of the sun, and which experienced more than 100 million times the pressure of Earth's atmosphere.

Under these extreme conditions, hydrogen atoms underwent fusion and released 1.3 megajoules of energy – the equivalent of 10 quadrillion watts of power for 100 trillionths of a second. This was NIF's highest energy yield to date (*Physical Review Letters*, doi.org/gqmvsd).

The new analysis shows that the experiment also brought the facility closer to the kind of fusion reaction that could eventually be used as an energy source by satisfying the so-called Lawson criterion for ignition, which states that the fusion heating must be high enough to overcome all physical processes that might cool the plasma.

"We determined that we reached Lawson's criterion, which proves that this is not only possible, but possible at NIF," says Annie Kritcher at NIF. "This is the first time we have crossed Lawson's criterion in the lab."

Sam Wurzel at the US Department of Energy says that crossing this criterion is crucial proof of ignition and a result that is likely to accelerate research and development in fusion science for both national security and energy applications.

"You get what's called a propagating burn: fusion causes more fusion which causes more fusion"

Lawson's criterion, formulated by physicist John Lawson in 1955, takes into account variables such as a plasma's density and how long it must be confined to create a sustained reaction. "You get what's called a propagating burn: fusion causes more fusion which causes more fusion which causes more fusion," says Steven Cowley at Princeton University.

The analysis tested experimental data against nine versions of Lawson's criterion, each dictating how different sets of measurements should relate to each other during ignition. It confirmed that ignition was reached according to all of them, overcoming the natural tendency of a reaction to cool and stop. Had the reaction not self-heated in this way, the energy yield would have been much smaller, says Cowley.

Since August 2021, NIF researchers have conducted four similar experiments that produced energy yields up to two-thirds of the 8 August value, but didn't reach ignition, says Kritcher. She says that the experiment is highly sensitive to small changes, such as barely perceptible differences in the material structure of each hydrogen capsule or small variations in the intensity of the lasers.

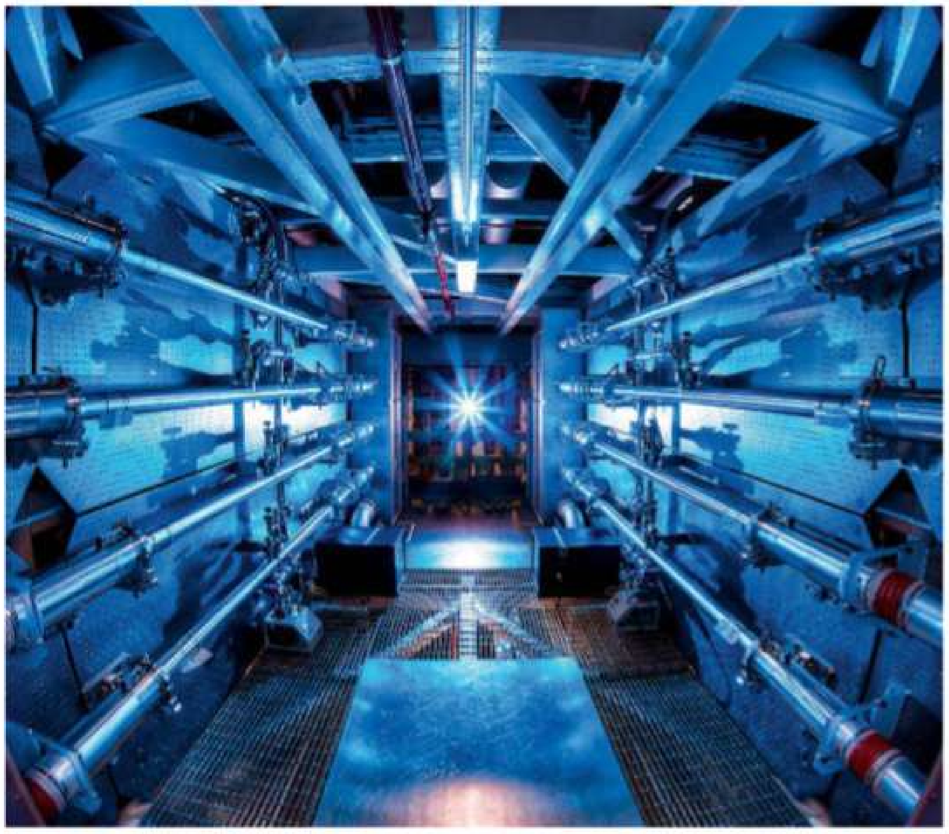
"If you start from a microscopically worse starting point, it's reflected in a much larger difference in the final energy yield," says Jeremy Chittenden at Imperial College London, who worked on the analysis. "The 8 August experiment was the best-case scenario."

Kritcher says that she and her colleagues have done "lots of diagnostic and scientific digging" in the past year to uncover the exact conditions that resulted in ignition. They determined that even the size of the tiny tube that fills the capsule with hydrogen, itself smaller than a chia seed at 2 millimetres, makes a big difference, as does the way hydrogen atoms arrange themselves inside it. Kritcher says that the NIF team wants to use this knowledge to not only replicate those conditions, but also make the experiment more resilient to small errors so it can reliably achieve ignition again and again.

"You don't want to be in a position where you've got to get absolutely everything just right in order to get ignition," says Chittenden.

Reliably and repeatedly achieving ignition at NIF would be significant, but one more hurdle remains before fusion-based power plants become a realistic possibility. Namely, the amount of energy produced after ignition must be as large or larger than the amount of energy put in by the lasers. The 8 August experiment made it about 72 per cent of the way there.

That would make harnessing fusion for clean power plants more feasible in the future. This may still be many years away – for commercial energy purposes, the fusion reaction would need an output of more than a hundred times the energy it requires for ignition, says Cowley. ▮



The National Ignition Facility at Lawrence Livermore National Laboratory, California

SCIENCE HISTORY IMAGES/ALAMY

Natural resources

Contaminated volcanic deposit exacerbated CO_2 shortage in US

Jeremy Hsu

THE US has a carbon dioxide shortage, intensified by natural contaminants found in the supply from an extinct volcano in Mississippi. This underground CO_2 source is particularly crucial for bubbly beverage makers and food processing companies.

The US has multiple sources of natural CO_2, but a reservoir under an uplifted area known as the Jackson Dome is the only large underground deposit east of the Mississippi river. It was created by a now-extinct volcano 880 metres below Jackson, Mississippi, which emitted huge amounts of CO_2 before falling silent about 66 million years ago, prior to the end of the Cretaceous Period.

Since oil and gas companies found the deposit in the 1970s, it has become a significant source of CO_2 for both US Gulf Coast oil production and a $1.5 billion market that includes food and beverage processing. It "represents almost 15 per cent of US merchant CO_2 capacity", says Maura Garvey at Intelligas Consulting in Massachusetts. "So it is a very important source for the market, especially the food and beverage industry which represents 70 per cent of demand."

ZORAN MIRCETIC/GETTY IMAGES

Beer brewers have been hit hard by a shortage of CO_2

The Jackson Dome deposit, owned by the Texas energy company Denbury, is an unusually pure natural source of CO_2 with about 98 per cent purity, says David Dockery at the Mississippi Department of Environmental Quality. That is because the CO_2 ended up in a reservoir of quartz sandstone that held only salt water, he says.

But companies that purify and liquefy CO_2 recently found that the supply contained elevated levels of benzene and sulphur, says Sam Rushing at Advanced Cryogenics, a consulting firm for the CO_2 industry in Florida. Benzene and sulphur are naturally occurring; benzene can be toxic at higher levels while sulphur can create a distasteful odour. Elevated levels of these chemicals made it more difficult or sometimes impossible to process the CO_2 to meet food and beverage standards.

Rushing and Garvey both say the issue may have stemmed from Denbury tapping alternative CO_2 wells at Jackson Dome. Denbury stated that the CO_2 being produced at Jackson Dome meets all "regulatory requirements" and "contractual specifications". A spokesperson for Denbury declined to go on the record about the cause of the recent issue.

Ammonia plants produce CO_2 along with fertiliser, but many have been undergoing scheduled shutdowns during the summer months when fertiliser isn't in demand. The result is that even a temporary supply disruption at Jackson Dome may have caught some customers off guard, even if they were anticipating a summer shortage because of the fertiliser plants going offline, says Garvey.

The supply issue at Jackson Dome may have been resolved, according to one company that produces beverage-grade CO_2, says Rushing. But the spectre of broader shortages still looms, as market demand has been outpacing supply in recent years. ▮

Microbiome

AI that recommends bespoke diets seems to ease constipation

AN ARTIFICIAL intelligence that analyses the microbiome of people with chronic constipation and recommends personalised diets may relieve symptoms more effectively than existing treatments.

The condition is usually treated with laxatives, by injecting fluid into the bowel or via dietary changes.

Previous studies suggest that the gut microbiome of someone with chronic constipation differs from that of someone without it, hinting that altering the microbiome could provide a long-term solution.

To test this idea, Tunali and his colleagues used data from previous studies to train an AI to analyse stool samples. The AI looked for bacteria that indicate the make-up of a person's microbiome and could be linked to chronic constipation.

They recruited 25 people with two or more symptoms of chronic constipation. For each person, the AI analysed one stool sample. It then suggested dietary changes intended to influence their microbiome to a dietitian, who devised an eating plan for each individual, which they followed for six weeks. However, the study didn't check if this diet resulted in microbiome changes.

Another 20 people with chronic constipation followed a standard 10-week treatment of the laxative sodium picosulphate and were told to consume more fibre and fluids.

After treatment, the people who ate a personalised diet had an average 250 per cent increase in weekly complete bowel movements (medRxiv, doi.org/h77w). Those in the other group saw such bowel movements increase by 33 per cent.

"The microbiome of someone with chronic constipation may differ from that of a healthy gut"

However, those on personalised diets had weekly appointments with a dietitian, whereas people on the standard treatment only received a one-off recommendation to increase fluid and fibre uptake.

The benefits of the personalised diet may, therefore, be due to regular dietitian appointments encouraging adherence to a fibre- and fluid-rich eating plan, says Kevin Whelan at King's College London. ▮

Carissa Wong

Space flight

Radiation threat to Mars astronauts

Simulated doses on a 1000-day mission exceed the safe limits set by space agencies

Alex Wilkins

A CREWED mission to Mars would expose astronauts to radiation levels higher than the safe limits set by space agencies, even with metal shielding, simulations have revealed.

There have been real-world and simulated studies of radiation doses in space, but these tend to be either time-limited or restricted in scope, such as only accounting for specific organs or focusing on men only.

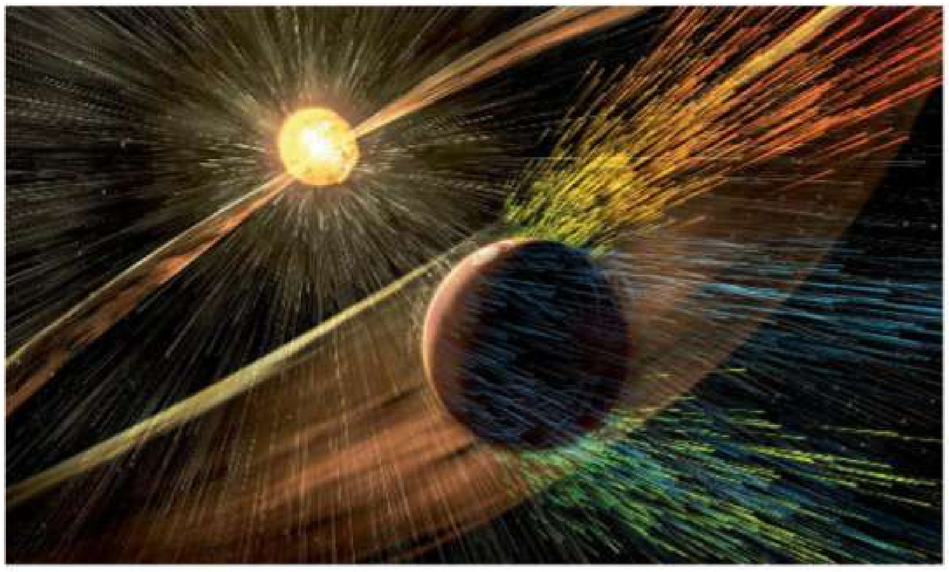
"Many calculations took a very simplistic approach, but we have done it in a more comprehensive way," says Dimitra Atri at New York University Abu Dhabi in the United Arab Emirates. "I wanted to know exactly what these numbers are so that I could make up my own judgement whether such missions are safe or not."

Atri and his team bombarded virtual models of male and female bodies with solar bursts and certain types of cosmic radiation using software designed to let particle accelerators track how particles move through matter.

They then estimated radiation levels for more than 40 body parts and organs during a Mars mission with 600 days spent in space and 400 days on the Martian surface, with and without aluminium shielding in the spacecraft.

Many of the radiation levels for individual organs were found to be above 1 sievert, which is the safe cumulative dose for an astronaut's career set by the European and Russian space agencies. NASA's guidance says the total career radiation dose shouldn't exceed 0.6 sieverts.

Illustration of Mars being bombarded by radiation from the sun



SCIENCE HISTORY IMAGES/ALAMY

Atri and his team then looked at the pathological effects of similar or lower radiation doses in the real world, such as in nuclear accidents, radiotherapy and medical studies. They found that even lower doses than their estimates could cause memory problems, thyroid cancer and cardiovascular problems (arXiv, doi.org/h7x9).

However, the results don't account for differences in how individuals might respond to the same dose of radiation. "These doses are in a grey zone, which is about 1 sievert," says Atri. "So it is certainly risky, and there will be a fraction of astronauts who are going to have a higher probability of getting cancer or maybe other diseases because of this, but maybe some will be fine."

Having this sort of data is important for any future space missions beyond Earth, says Libby Jackson at the UK Space Agency. She adds that her agency and others are working on ways to mitigate radiation, such as building shelters under the Martian surface and more advanced shielding on spacecraft.

The dangers of space radiation might be even worse than Atri's findings suggest, says Keith Siew at University College London. Cosmic radiation includes charged particles that are heavier than protons or helium, which aren't accounted for in the analysis. The effects of these heavy particles on the body, for which we have limited data, could be far more damaging than those of other radiation sources, says Siew. ▮

Biotechnology

Cornea made from pig collagen may restore sight

CORNEAS made from pig collagen have restored sight for people who were previously legally blind or visually impaired.

More than 12 million people globally have corneal blindness, which can occur when the eyes' protective outer layer becomes cloudy or misshapen from damage or disease. Because corneal transplants normally require a human donor, only 1 out of every 70 people in need receive one.

Mehrdad Rafat at Linköping University in Sweden and his colleagues manufactured a flexible yet resilient dome that resembles a contact lens by extracting and purifying collagen from pig skin. Following successful trials in pigs, the team began testing the artificial corneas in human volunteers.

All 20 people in the trial had corneal blindness caused by a condition called keratoconus, in which the cornea thins and bulges outward from the centre of the eye. Fourteen were legally blind and six had severely impaired sight.

The procedure improved vision in all of the participants. Three of the formerly blind participants had 20/20 vision afterwards (*Nature Biotechnology*, doi.org/h7vj).

"We got much better results than we expected," says Rafat. Two years after the operations, nobody reported serious complications or adverse side effects.

Esen Akpek at Johns Hopkins University in Maryland says people with keratoconus can often be fitted with custom contact lenses, and that previous alternatives to donor corneas haven't taken off. "It will not cure anyone that cannot be cured with the currently available technology," says Akpek.

"Three of the formerly blind participants had 20/20 vision following the procedure"

Rafat isn't sure what the final cost of the procedure will be, but says it should be more affordable than donor transplants, which can cost tens of thousands of dollars. Further clinical trials will be needed before the cornea could become more widely available. ▮

Corryn Wetzel

Astronomy

Nearby galaxies may lack dark matter to hold them together

Leah Crane

A NEARBY galaxy cluster called the Fornax Cluster is ripping apart its dwarf galaxies. They appear to be tearing up far more easily than we would expect, suggesting that they may not contain any dark matter.

In the standard model of cosmology, called lambda-CDM, most galaxies should contain a healthy dollop of dark matter, which helps hold them together.

But when Elena Asencio at the University of Bonn in Germany and her colleagues analysed 353 dwarf galaxies in the Fornax Cluster, far more of them than expected were distorted by the pull of other galaxies, especially near the centre of the cluster. This seems to indicate that they have little to no dark matter to hold them together.

However, with no dark matter, it is difficult to understand how these galaxies could exist at all.

The researchers performed simulations of how these galaxies would behave under an alternative model for gravity called modified Newtonian dynamics, or MOND. In this model, isolated galaxies are expected to behave differently from those in a cluster that are subject to strong external gravitational fields.

The team found that the MOND model correctly predicted the warping of the Fornax Cluster's dwarf galaxies (*Monthly Notices of the Royal Astronomical Society*, doi.org/gqmfvm).

"It's very difficult to explain it any other way," says Indranil Banik at the University of St Andrews in the UK, part of the team.

However, MOND is controversial, largely because it doesn't match established observations of the cosmic microwave background (CMB) – a sea of radiation left over from the big bang – and is difficult to reconcile with some long-accepted theories such as Albert Einstein's general theory of relativity. ▮

Coronavirus

No pregnancy complications with covid-19 vaccines

Jason Arunn Murugesu

THE most commonly used covid-19 vaccines are safe in pregnancy, a study has found.

There has been a lack of clarity over the risks of covid-19 and vaccines against it during pregnancy throughout much of the pandemic. In the UK, vaccines began being rolled out in December 2020, but weren't offered to pregnant people until April 2021. Worldwide, pregnant people are now encouraged to get vaccinated. But in the UK, only 3 in 5 women who gave birth in January 2022 had received at least one dose.

To better understand the vaccines' safety profile, Manish Sadarangani at the British Columbia Children's Hospital Research Institute in Canada and his colleagues surveyed 191,360 people, aged 15 to 49, between December 2020 and November 2021.

The participants self-reported any health issues they experienced in the seven days after they received the first or second dose of a Pfizer/BioNTech or Moderna vaccine.

A pregnant person receiving the Pfizer/BioNTech vaccine

HANNAH BEIER/REUTERS/ALAMY

The participants, of whom more than 97 per cent identified as women, were split into three groups: pregnant people who were vaccinated against covid-19, unvaccinated pregnant people and people who were vaccinated but not pregnant.

In the seven days after a first vaccine dose, 1.5 per cent of the 5597 vaccinated pregnant people reported a stillbirth or miscarriage, which resulted in hospitalisation in some cases, compared with 2.1 per cent of the 339 unvaccinated pregnant people (*The Lancet Infectious Diseases*, doi.org/h7w7).

For comparison, the researchers assessed the hospitalisation rate of the non-pregnant but vaccinated participants. Of these, just 0.6 per cent were admitted for any reason in the seven days after their first vaccine dose.

"The one thing that all women who are pregnant worry about is the baby," says Allison McGeer at the University of Toronto in Canada, a co-author of the study. "In this sizable study, we were unable to detect any adverse events associated with pregnancy for those who got the vaccine."

Other pregnancy complications, such as vaginal bleeding, were rarely reported, but rates were similar between all pregnant participants.

"It is very reassuring that there is no evidence of any safety concerns associated with vaccination in pregnancy, especially as high levels of vaccination hesitancy in pregnancy persist," says Sarah Stock at the University of Edinburgh in the UK.

> "We were unable to detect any adverse events with pregnancy for those who got the vaccine"

The team also found that just 4 per cent of pregnant people reported less serious health issues, such as headaches, in the seven days following their first vaccine dose, rising to 7.5 per cent after a second dose.

Meanwhile, 6.3 per cent of the vaccinated non-pregnant people reported mild side effects in the week after dose one, increasing to 11.3 per cent in the seven days after dose two. Pregnancy may change the immune system, leading to fewer mild symptoms post-vaccination, says McGeer.

The World Health Organization, the UK's National Health Service and the US Centers for Disease Control and Prevention all recommend that pregnant people get vaccinated against the coronavirus.

According to a study published in July, having covid-19 in late pregnancy is linked to a seven-fold higher risk of premature birth. A more recent analysis found that pregnant people with covid-19 are more likely to experience heart complications than those who aren't pregnant. ▮

Astronomy

Hunt for interstellar meteorite on sea floor

Alex Wilkins

SHUTTERSTOCK/TRIFF

An artist's impression of a meteor burning up in Earth's atmosphere

ASTRONOMERS who claim to have spotted an interstellar meteor hitting Earth are trying to raise $1.6 million to mount an expedition to search for fragments that may remain on the sea floor north of Papua New Guinea. But the claim remains controversial and other researchers say the odds of finding anything are minimal.

There have only been two confirmed observations of interstellar objects: 'Oumuamua, a cigar-shaped asteroid spotted in 2017, and Borisov, a comet seen in 2019. A few months before Borisov was seen, Avi Loeb and Amir Siraj at Harvard University claimed to have identified an interstellar rock by crunching publicly available data collected from classified US government sensors, which cover nearly the entire Earth.

According to the pair, the roughly 0.5-metre-wide rock, called CNEOS 2014-01-08, entered Earth's atmosphere from an interstellar trajectory in 2014 before burning up, but not everyone was convinced. The US government didn't release measurement uncertainties for the data, which meant that the object couldn't be verified as being interstellar.

But in April this year, US Space Command, a division of the Department of Defense, released a statement about the meteor, stating "the velocity estimate reported to NASA is sufficiently accurate to indicate an interstellar trajectory". It still hadn't released the actual uncertainties, but Loeb and Siraj were encouraged.

Alongside its statement, US Space Command released a light curve for the meteor, a record of its brightness in Earth's atmosphere over time that Siraj says can be used to infer the rock's composition. In a new analysis co-authored with Tim Gallaudet at Ocean STL Consulting, the pair say the meteor probably contained some form of iron, suggesting metallic fragments may have made it to Earth's surface (arxiv.org/abs/2208.00092).

"It's an extreme outlier in terms of composition, and it would be very difficult to get that kind of tensile strength without a lot of metal," says Siraj.

$1.6m

Cost of proposed expedition to hunt for meteorite fragments

The sensor readings give a 10-by-10-kilometre area of the sky where the meteor entered the atmosphere. Using that data, along with models of winds and ocean currents, the researchers say they have traced its final resting point to 100 square kilometres of the Bismarck sea, north of Papua New Guinea.

They now want to launch a 10-day expedition to collect possible meteorite fragments by towing a box covered in magnets across the ocean floor – as the fragments contain iron, they should be magnetic.

The researchers hope to fund the $1.6 million expedition through private donations, though they are about $1 million short. Siraj says they are already in contact with oceanographic experts, including one who carried out a similar ocean meteorite expedition in 2018.

But there is still the problem of the missing data, says Peter Brown at Western University in Ontario, Canada. "I don't think the science community is going to buy into that unless the raw data is released, which I think is not likely."

Even if data for the meteor fireball is released, the ocean depth and potential for strong currents to have transported the fragments away from the search area makes success unlikely, says Alan Fitzsimmons at Queen's University Belfast, UK. "It's going to be much worse than looking for a needle in a haystack." ■

Evolution

Losing parts of our voice box may have helped speech

Clare Wilson

THE loss of small tissue structures from the voice box may have led to the evolution of human speech.

While many animals make calls to communicate, the evolution of human speech seems to have required anatomical changes.

In humans, the vocal cords are flaps of tissue that vibrate as air is expelled from the lungs, allowing us to make "voiced", rather than breathy, sounds. Some non-human primates also have "vocal membranes", a small extension of the vocal cords that makes their sounds louder and higher, but also irregular and harder to control.

These membranes may have been lost in humans when our ancestors diverged from chimpanzees, says Tecumseh Fitch at the University of Vienna in Austria.

To better understand this loss, Fitch's team scanned the voice box, or larynx, of 43 species of dead or anaesthetised apes and monkeys. All had this vocal cord extension (*Science*, doi.org/gqm8zm).

The team also analysed videos of the voice boxes of an anaesthetised chimpanzee, rhesus macaques and squirrel monkeys. In these animals, vibration and collision of the vocal membranes were the primary source of their calls, as their vocal cords were in motion less often.

If humans had vocal membranes, our speech would probably sound more rough and variable, with abrupt pitch changes, says Fitch.

"A key thing that distinguishes human speech from animal sounds is our fine-grained control over the sounds we make. That is only possible if our vocal apparatus is easy for our brains to control," says Richard Futrell at the University of California, Irvine.

But Adriano Lameira at the University of Warwick, UK, says many apes and monkeys can make quieter and more controlled noises, as well as loud and irregular ones. ■

AN IMPORTANT MESSAGE FROM PROFESSOR NICK LEMOINE CBE MD PHD FMEDSCI, CHAIR OF THE MEDICAL RESEARCH FOUNDATION

Gifts in Wills could be the key to protecting the future of human health

Our experience of COVID-19 shows how suddenly a global health challenge can appear. As someone interested in science, you will understand that while nobody can predict what we will face next, we can be certain that the future will bring many more threats to human health.

As Chair of the Medical Research Foundation – the charitable arm of the Medical Research Council – I have seen the incredible impact that individuals who remember the Foundation in their Wills can have on the future of our health and wellbeing here in the UK. These gifts fund research and researchers which can have far-reaching implications for human health.

With a gift in your Will you can play a key role in providing the science that will protect the health of future generations.

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Without support at the crucial early stages, researchers like Dr Kaforou can be forced to abandon their passion and leave science altogether, with an immeasurable loss to future human health. Gifts in Wills provide the long term funding and security that allows the Foundation to invest in projects like Dr Kaforou's and lay the foundations for quality research in years to come.

Your Will can fund the rational response to health challenges that medical science provides.

> **"As scientists, our duty is to secure the future of research for the generations that follow."**
>
> Professor Fiona Watt, Patron of the Medical Research Foundation and Director of the European Molecular Biology Organization.

While we don't know what the future holds for human health in the UK, we do know that research, and the brilliant scientists driving that research forward, are the key to meeting those challenges for years to come.

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"The funding I received through the Medical Research Foundation will be transformative for my research." Dr Myrsini Kaforou

But many of these scientists rely on the generosity and foresight of fellow members of the public – people like you, who understand the power of science and are willing to leave a gift to medical research in their Wills. At the Medical Research Foundation, over 90% of our voluntary income comes from individuals who choose to include a gift in their Will – they are crucial in the Foundation's ability to fund research that will enable the next generation of scientists to make real world discoveries in the future.

I firmly believe that a gift in your Will to the Medical Research Foundation is an excellent investment and will have a lasting impact on science and on the future of human health in the UK.

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Professor Nick Lemoine CBE MD PhD FMedSci
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Cognition

Why thinking long and hard can leave you mentally exhausted

Clare Wilson

THINKING hard for several hours can leave us feeling mentally tired, and now we may know why. Prolonged concentration leads to the build-up of a compound called glutamate in regions at the front of the brain.

This may explain why we avoid difficult tasks when mentally fatigued: a glutamate overload makes more mental work difficult. Excess glutamate can be harmful, says Antonius Wiehler at the Paris Brain Institute in France, who led the research. "The brain wants to avoid this, so it is trying to reduce activity." Very high glutamate can be toxic to brain cells.

Many of us have experienced mental weariness after a hard day of thinking, but until now, we didn't know why. The brain doesn't seem to run out of energy after working hard and even when we aren't thinking about anything specific, some brain regions, called the "default mode network", are as active as ever.

To learn more, Wiehler and his team used a technique called magnetic resonance spectroscopy (MRS), which harmlessly measures levels of chemicals in living tissue.

The researchers focused on a region towards the front and sides of the brain called the lateral prefrontal cortex, which previous work has shown is involved in difficult mental tasks.

> "Many of us have experienced mental weariness after a hard day of thinking"

The team asked 40 people to do memory tasks while lying in an MRS scanner. These included watching sequences of numbers appear on a screen and stating if the current number was the same as a previous one. Twenty-six of the participants did a harder version of this task, while the other 14 were given an easier one.

The levels of eight brain chemicals were measured, including glutamate, the main signalling chemical that operates between neurons.

After completing the memory tasks for 6 hours, those doing the harder version had raised levels of glutamate in their lateral prefrontal cortex compared with at the start of the experiment (*Current Biology*, doi.org/gqm8kv). In those doing the easier task, levels stayed about the same. Across all participants, there was no rise in the other seven brain chemicals that were measured.

The researchers also investigated whether mental fatigue affected decision-making. They did this by interspersing the memory task with different exercises, such as one where people chose between getting a sum of money straight away or a different one later.

As the participants doing the harder task felt more mentally tired and had an accumulation of glutamate, they shifted to options that gave a small reward immediately. This could be an example of us avoiding difficult mental tasks, such as calculating which choice to make, to prevent the accumulation of potentially harmful glutamate levels.

Measuring brain glutamate could be used to reveal how hard a region of the brain has been working, says Reto Huber at the University of Zurich in Switzerland. "We never had a good measure for that on the molecular or neurotransmitter [level]. This looks really promising," he says.

It could potentially be used by doctors to assess people with conditions that can make concentrating difficult, such as brain fog after covid-19 and attention deficit hyperactivity disorder in children, he says. ▮

Technology

Robot submarine scans seabed and classifies rubbish

AN UNDERWATER robot can autonomously check the bottom of the sea to identify plastic, rubber, glass and metal rubbish using artificial intelligence image recognition. This could help focus limited budgets for clean-ups on the most toxic and environmentally damaging materials.

Trygve Olav Fossum and his colleagues at the Norwegian firm Skarv Technologies created a 45-kilogram underwater robot equipped with stereo cameras, while researchers at Ecotone, another firm in Norway, produced a spectrometer that can identify the material an object is made of even through metres of murky water.

The robot scours the seabed at a distance of 2 metres, tracing a methodical route up and down in rows like a tractor ploughing a field, collecting data as it goes and plotting it on a map using GPS readings.

An AI model, which was trained on 28,000 images of underwater debris that had all been accurately tagged with a description, then takes the images and data from the robot's survey and classifies them. This information can be turned into colour-coordinated maps that are invaluable to clean-up operations.

In a bay in Bergen, Norway, called Store Lungegårdsvann, the team identified a total of 3894 objects and classified them into categories: bottles, including glass ones, plastics, anchors, tyres, metal and other items. The group also added a category for starfish, creating the bonus of surveying these animals in the bay (arXiv, doi.org/h7w3).

SKARV TECHNOLOGIES AS

The robot searches for trash at the bottom of a bay in Bergen, Norway

"We estimated that there's somewhere around 150 to 300 tonnes of trash in the bay," says Olav Fossum.

The problem of identification is made more difficult because objects tend to be partially embedded in the seabed, but mapping out the most dangerous material is essential to make the most of clean-up efforts by human divers, he says.

"Glass isn't really polluting – it's inert. So if you know there's an area with a lot of glass, you probably can exclude that from the clean-up effort and focus on things that are putting heavy metals into the environment," he says. ▮

Matthew Sparkes

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Big data

Battle over Virginia's data centres

Big Tech and civil war enthusiasts are clashing over efforts to build new data centres near historic US battlefields, writes **Jeremy Hsu**

THE rural landscape of northern Virginia is hallowed ground for US civil war enthusiasts. Across its open farmlands criss-crossed with split-rail fences, many of the most important civil war battles took place, such as the first major clash of armies at the Battle of First Manassas. Today, there are spent ammunitions, memorabilia and even lost graves still to be uncovered. The most popular battlefields attract more than half a million tourists a year.

A new conflict is now playing out at these sites, between some of the world's largest technology firms and preservationists. Northern Virginia has evolved beyond a historical hotspot to become home to Loudon County's Data Center Alley – the largest concentration of data centres in the world. And as Data Center Alley becomes even more crowded, developers are eying land near battlefields such as Brandy Station in Culpeper County, site of the largest cavalry battle in North America.

"Culpeper County is one of the most visited counties in the Commonwealth because of its civil war battlefields and its revolutionary war history," says Clark Hall, a local historian and preservationist. "And if you eviscerate its assets, then guess what? People won't come."

About 160 years ago, the northern Virginia region became a wartime crossroads for rival armies after 11 southern slave-holding states seceded from the US to form the Confederate States of America. Over the course of four years, Union and Confederate fighters clashed frequently and more than 620,000 people died while serving in the rival armies.

Today, the same region is home to more than 100 of the largest "hyperscale" data centres – 20 per cent of the world's total – owned or leased by companies such as Amazon, Google and Microsoft. Each resembles a giant warehouse filled with tens of thousands of computer servers for cloud computing.

"Amazon swooped in and bought a horse farm in agricultural land and just shocked everybody"

Virginia's data centre boom started in 2008 when the state began offering tax incentives to data centre developers, says Josh Levi, president of the Data Center Coalition. This snowballed as more fibre-optic networks were built within the state and connected to global networks. Virginia Beach, for example, hosts a crucial connection point for submarine internet cables – owned by companies such as Google, Meta and Microsoft – that carry data between the US, Europe and South America.

It has been a boon for the local economy and demand for data centres has soared in the past two years thanks to the rise in remote working during the pandemic. However, finding the right place to put new data centres isn't easy.

Take a recent Amazon land purchase in Culpeper County. The company has proposals for two six-storey data centres covering more than 4 hectares, which county officials approved in April 2022. Six landowners responded by filing a lawsuit alleging that the decision violates the county's comprehensive plan for land use established in 2015. That case is currently being considered by the Culpeper Circuit Court.

The location of Amazon's proposed $500 million facility has clear sight of Hansbrough Ridge, where early fighting took place between Union and Confederate cavalry during the 1863 Battle of Brandy Station. That ridge also holds the rocky foundations of many huts built by thousands of Union soldiers who camped there later in the civil war and is set to become part of a state battlefield park.

"It's a very rural county, Culpeper – cows and corn," says Andrew Gutowski at the Culpeper Alliance for Balanced Growth, a community advocacy group. "Amazon swooped in and bought a horse farm in agricultural land and just shocked everybody."

Amazon didn't respond to *New Scientist*'s request for comment. John Foote, a land-use attorney part of the team representing Amazon in its push to develop data centres in Culpeper County, has previously told local news the site is particularly good due to its vicinity to power and internet cables. "The magic elixir is access to fibre and power," he said.

While civil war enthusiasts and historical preservationists are fighting the data centres, many counties are vying for the business to boost local tax revenue. Some counties had previously set aside land specifically for so-called technology zones that could host data centres. But controversy arose when developers pressed county officials to approve the rezoning of much cheaper agricultural land near state and national battlefield parks.

Ultimately, many of the people opposing the expansive plans for new data centres say they would be happy if the new sites were only in those zones already designated for technology development, says Jim Campi at the American Battlefield Trust in Washington DC, one of the organisations opposing the data centre sites near the battlefields of both Prince William and Culpeper counties. "There is no reason you can't balance data centre development and historic preservation," he says.

SHUTTERSTOCK/EWY MEDIA

Data centres are getting closer to Manassas National Battlefield Park

Health

Veggie diet can raise risk of a hip fracture

THE risk of breaking a hip is a third higher for vegetarian women than those who are regular meat eaters, according to a large UK study.

This may be down to meat-free diets tending to have less protein, which helps build muscle mass, and possible deficiencies in vitamins and minerals, such as calcium and vitamin B12, which help strengthen bones.

James Webster at the University of Leeds, UK, and his team tapped into a large ongoing study tracking over 26,000 women in the UK for about 20 years, aged between 35 and 69 at recruitment. Overall, about 3 per cent of them broke their hip in that time. Those who were vegetarian had a 33 per cent higher risk of this compared with those who consumed meat at least five times a week (*BMC Medicine*, doi.org/h7w4). **Clare Wilson**

CURRENT BIOLOGY/KORNDER ET AL (CC BY-SA)

Wildlife

Hibernation slows ageing in some bats

BATS may age more slowly during hibernation compared with when they are active. They are the second type of hibernating animal found to do this, alongside marmots.

Gerald Wilkinson at the University of Maryland and his team used an existing technique to measure the accumulation of certain chemical labels on DNA to calculate biological age in a species of hibernating brown bat (*Eptesicus fuscus*). They found reduced signs of ageing biomarkers when hibernating (*Proceedings of the Royal Society B*, doi.org/h7w5).

It makes sense that hibernating animals would age more slowly, says Christopher Turbill at Western Sydney University in Australia, as this could extend the period to successfully reproduce, which would otherwise be reduced by hibernation. **Alex Wilkins**

Marine biology

Sponges expel mucus with slow-motion 'sneezes'

SEA sponges "sneeze" in slow motion to get rid of the sand and pollutants that they suck into their bodies, and the expelled mucus may be an important food source for other marine organisms.

Taking up to 50 minutes to complete, sponge sneezes use contractions to propel unwanted substances from pores called ostia in long, sticky strings of mucus. These regular releases of "fresh biomass" may help explain why fish and crustaceans live in or near sea sponges, says Niklas Kornder at the University of Amsterdam.

Kornder and his colleagues observed the sneezes by collecting several stove-pipe sponges off the island of Curacao in the Caribbean and recording them in their laboratory using time-lapse video. They also filmed another stove-pipe sponge in the sea and studied a video of a *Chelonaplysilla* sponge (pictured) taken in Australia.

Each video showed particle-filled mucus travelling out of the ostia pores. At the surface, the mucus followed a network of "mucus highways" – white lines, probably made of collagen, intersecting at numerous junctions where the mucus would start to form globs. Then, the sponge would contract and the stringy clumps of mucus would release into the water.

The team also observed shrimp and other small crustaceans eating the nutrient-rich mucus, and even some small fish looking as though they were interested in it (*Current Biology*, doi.org/gqm35m).

At an average speed of 2 millionths of a metre per second, these sneezes may be so slow because sponges lack both muscle cells and nerve cells, says Kornder. **Christa Lesté-Lasserre**

Really brief

MING-CHIH HUANG, JOURNAL OF NATURAL HISTORY

Giant crustacean is new to science

A 26-centimetre-long armoured crustacean kept in a Japanese aquarium has been identified as a species new to science. The giant isopod was first found in the Gulf of Mexico and misidentified until a researcher sequenced its DNA (*Journal of Natural History*, doi.org/h7wv).

Soft robot beats cheetah for speed

A squishy robot smaller than a postage stamp can run 70 of its body lengths every second – more than three times faster than a cheetah, relative to its body size. It might eventually be used to deliver drugs or perform procedures inside the human body (*Nature Communications*, doi.org/gqm35g).

Eye sockets aided *T. rex*'s deadly bite

Tyrannosaurus rex's eye sockets may have helped it evolve one of the most powerful bites of all time. Reconstructions suggest that the predators' unusual keyhole-shaped sockets dissipate the stresses of biting hard more effectively than round eye sockets (*Communications Biology*, doi.org/h7ww).

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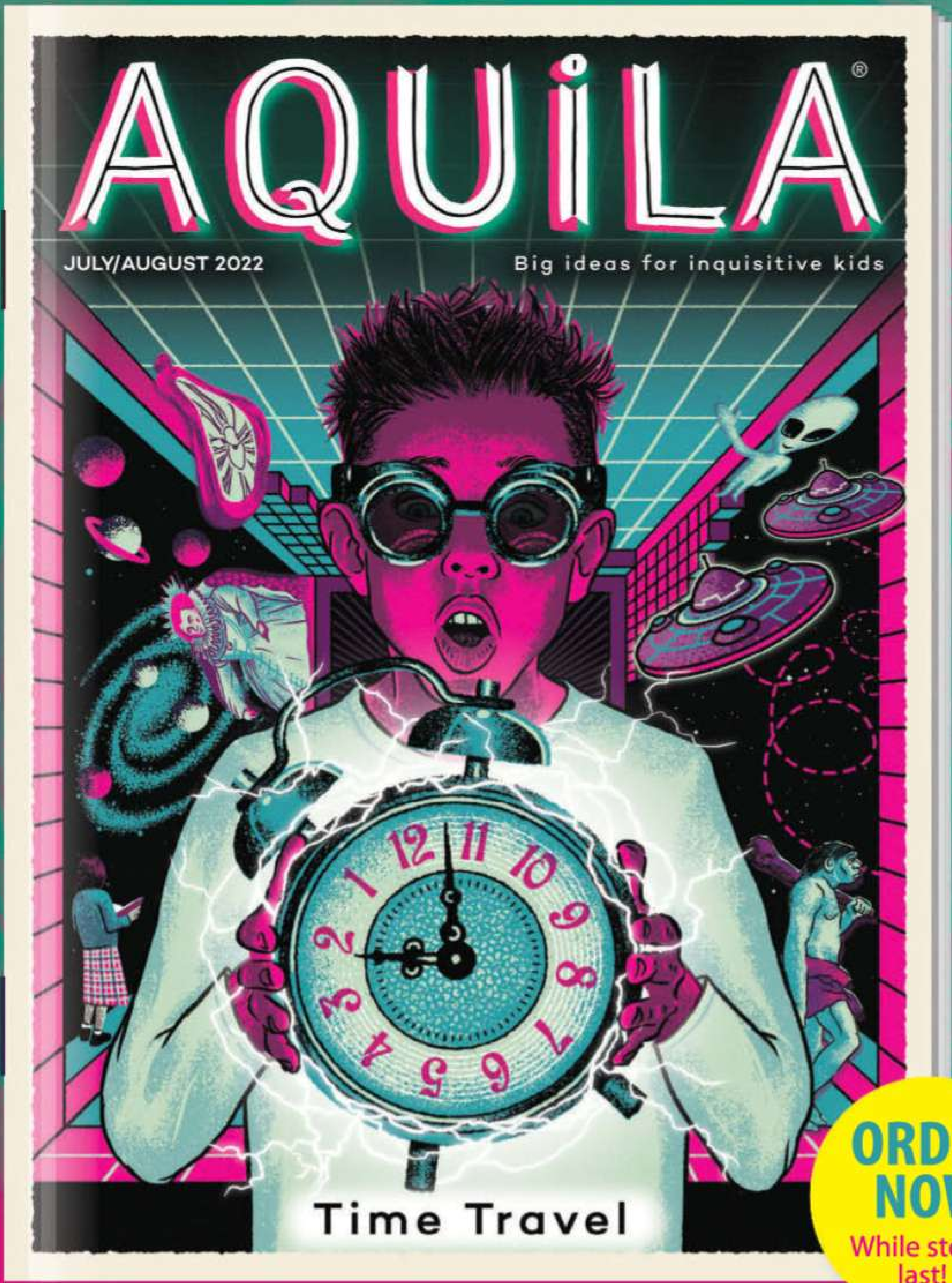

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Views

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Jacob Aron role-plays as a city-dwelling cat on a mission p32

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How to cope with the darker side of daydreaming p37

Comment

Not such a class act

While addressing mental illness at school is well intentioned, it may not always have a positive effect, says **Lucy Foulkes**

MICHELLE D'URBANO

TEENAGERS are experiencing a mental health crisis. I am not just talking about the increase in mental health problems that have been reported in them over the past decade or so. I am talking about what UK schools are being asked to do in response.

Many secondary schools in the UK – which educate those aged 11 up to 18 – now teach mental health skills, such as mindfulness or techniques from cognitive behaviour therapy (CBT). In a "universal" approach, these lessons are taught to all students, regardless of their level of need. The idea is to give all teenagers helpful coping skills, which will alleviate current mental health problems or prevent future difficulties from starting.

This sounds excellent on paper, but the trouble is, it doesn't work very well in reality. Research shows that when universal lessons do reduce symptoms of mental health problems, the effect is small: on average, teenagers who receive these classes only score slightly lower on questionnaires measuring anxiety or depression than those who don't receive them.

More concerningly, the lessons might actually increase symptoms. A study published a few weeks ago, involving 8376 students in 84 UK schools, found that teenagers who received 10 mindfulness lessons reported more symptoms of depression than those who just had their usual lessons. Other studies have found that teaching teenagers CBT skills at school led to a small increase in depression and anxiety symptoms. In fact, when teenagers are asked what they think about mental health lessons, some say they find them helpful, but others say the focus on negative thoughts made them feel more stressed and unhappy.

Such findings shouldn't be surprising. The whole premise of these classes is that students should notice their negative thoughts and feelings, label them and then carry out exercises to try to accept or change them. But it can be really difficult to change how you think and feel, especially without one-to-one support. School mental health lessons may be inadvertently teaching teenagers to ruminate on negative thoughts and feelings without giving them any real ability to manage these experiences, which could increase their distress.

It is well-established that psychological therapy doesn't help everyone and can even lead to increased mental health problems in some people. Since school mental health lessons are based on principles from psychological therapy, it is a reasonable and urgent hypothesis that they might have a harmful effect too, at least for some individuals.

There are other issues with universal approaches. By definition, they ignore the immense variety of personalities, needs and circumstances that exist within a class of students – and yet understanding this variation may be key to helping each individual. In addition, lessons about coping skills don't address the root causes of mental health problems and instead tell the individual to manage their distress themselves, which can be unfair and unrealistic.

The question is what we do instead, because there are many teenagers who badly need mental health support and aren't getting it. Two options may be more fruitful than universal approaches. First, more funds and effort could be channelled into one-to-one support, either via the National Health Service or experts working within schools. Second, more efforts could be made upstream, to reduce the issues, such as bullying and financial insecurity, that make teenagers so vulnerable to mental health problems in the first place.

We need to do a lot. But we also need to press pause and think about what not to do, because teaching mental health skills to everyone, while appealing on paper, isn't stemming the problem – and might even be making matters worse. ▮

Lucy Foulkes is a psychologist specialising in adolescent mental health @lfoulkesy

This changes everything

Campsite coding Deerpunk costumes, tacos delivered by drones and a game called "Beerocracy" featured at this year's ToorCamp for hackers – it was a blast, writes **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest novel is *The Future of Another Timeline* and they co-host the Hugo-nominated podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is **techsploitation.com**

Annalee's week

What I'm reading

Neon Yang's The Genesis of Misery, *about a messed-up kid from the slums of the galactic empire who figures out how to pilot a dangerous alien vessel.*

What I'm watching

Prey, *a worthy successor to the very underrated film* Alien vs. Predator.

What I'm working on

Preparing to co-host the Hugo Awards ceremony at the World Science Fiction Convention in September.

This column appears monthly. Up next week: Beronda L. Montgomery

LIGHTS in every colour of the rainbow illuminated the forest. People wearing antlers on their heads wandered through a barrage of soap bubbles that released puffs of dry ice smoke as they popped. In the distance, I could hear the sound of music and video game bleeps. No, it wasn't a rave, nor had I gone back in time to some kind of Druid ritual. I was on a tiny island off the coast of Washington in the US Pacific north-west, attending a five-day festival for hackers called ToorCamp.

According to security researcher David Hulton, one of the camp's founders, it is the only hacker camp in the US ("toor" is "root" spelled backwards, a nod to the goal of hackers to "get root", which means achieving access to the deepest level of code on a computer). Modelled on European summer events like Germany's Chaos Communication Camp and the UK's EMF camp, it is a place where artists, makers, tech tinkerers, hackers and amateur scientists meet to share ideas and toast marshmallows under the stars.

The theme of 2022's ToorCamp, which is held every two years in July, was "deerpunk". The theme inspired art and costumes that merged cyberpunk with the natural landscape where the camp was held, a modest private resort where yurts overlook a tiny beach and an organic garden supplied edible flowers to groups who entered the hacker cooking contest. Under a huge dome, experts gave talks on everything from crypto scams and ham radio tricks, to building autonomous sailboats for hauling cargo.

Bucking the stereotype of geeks who hide from the sunlight in basement server farms, these are nerds who love to combine outdoor adventure with soldering circuit boards and software tricks.

Hacker camps are different from typical tech gatherings in other ways, too. Nobody is here to promote their start-up and most attendees have a healthy distrust of corporate and government authorities. They have stickers on their laptops that say things like, "I void warranties for a living". But there is a wholesome family vibe – it is more *Doctor Who* than *Black Mirror*. This year, ToorCamp hosted a couple of dozen high school students who came to learn more about careers in technology. Two of them gave a talk about teaching non-programmers to create machine learning algorithms using a "visual programming language" that allows people to write code using graphics. They told me that they hope to break down barriers to entry for people who want to shape the future of AI.

> **"Please do not try to hack your card. If you attempt, the outcome may be rewarding for you. And we hate that"**

At ToorCamp, the lines between technology, politics and culture were blurred. In one area, called Beerocracy, attendees could try a terrifying drinking game where anyone who wanted beer had to wait in line, answer obnoxious questions from "agents" and fill out endless, complicated forms to get alcohol. If you wanted a second round, the forms got a lot longer. But if you didn't have the right colour pen, all hope wasn't lost. "Bribes accepted", a sign outside read. (I offered up a tin of candy.) Somehow, the game became weirdly fun, while also reminding everyone that bureaucracy is the enemy of freedom.

ToorCamp was on an island with pretty bad cell reception, so a group called ShadyTel built an extremely local telephone system that anyone could plug into. They also created a fake digital currency called ShadyBucks, complete with credit cards. The cards came with instructions that read: "Please do not try to hack your card or the bank. If you attempt, the outcome may be rewarding for you. And we hate that." Of course, the hacking commenced immediately. By the last day of camp, several people managed to have more ShadyBucks on their cards than there had ever been in the bank.

We also managed to use the ShadyTel payphones to order tacos delivered by drone. Just call 4-NFT, because at ToorCamp, NFT stands for "nifty flying tacos". Though the games at ToorCamp were silly, they also had a serious side. More than anything, hackers love to understand how systems work and make them better. When a system isn't working – whether it is a bureaucracy or a currency – it can't go unchallenged.

Like many people at ToorCamp, I came to have fun through sly trickery and an earnest desire to build a better world. ToorCamp proved to be a brilliant model of constructive disobedience, where people questioned the status quo by building a new one. It would be easy for a place like this to exude a "burn it all down" sensibility that is all too relatable in our world right now. But instead, organisers encouraged campers to imagine new ways to build everything from phone networks and banks, to schools and software. For a few precious days, we escaped into a small, autonomous society devoted to reimagining all that exists. And it felt good. ▮

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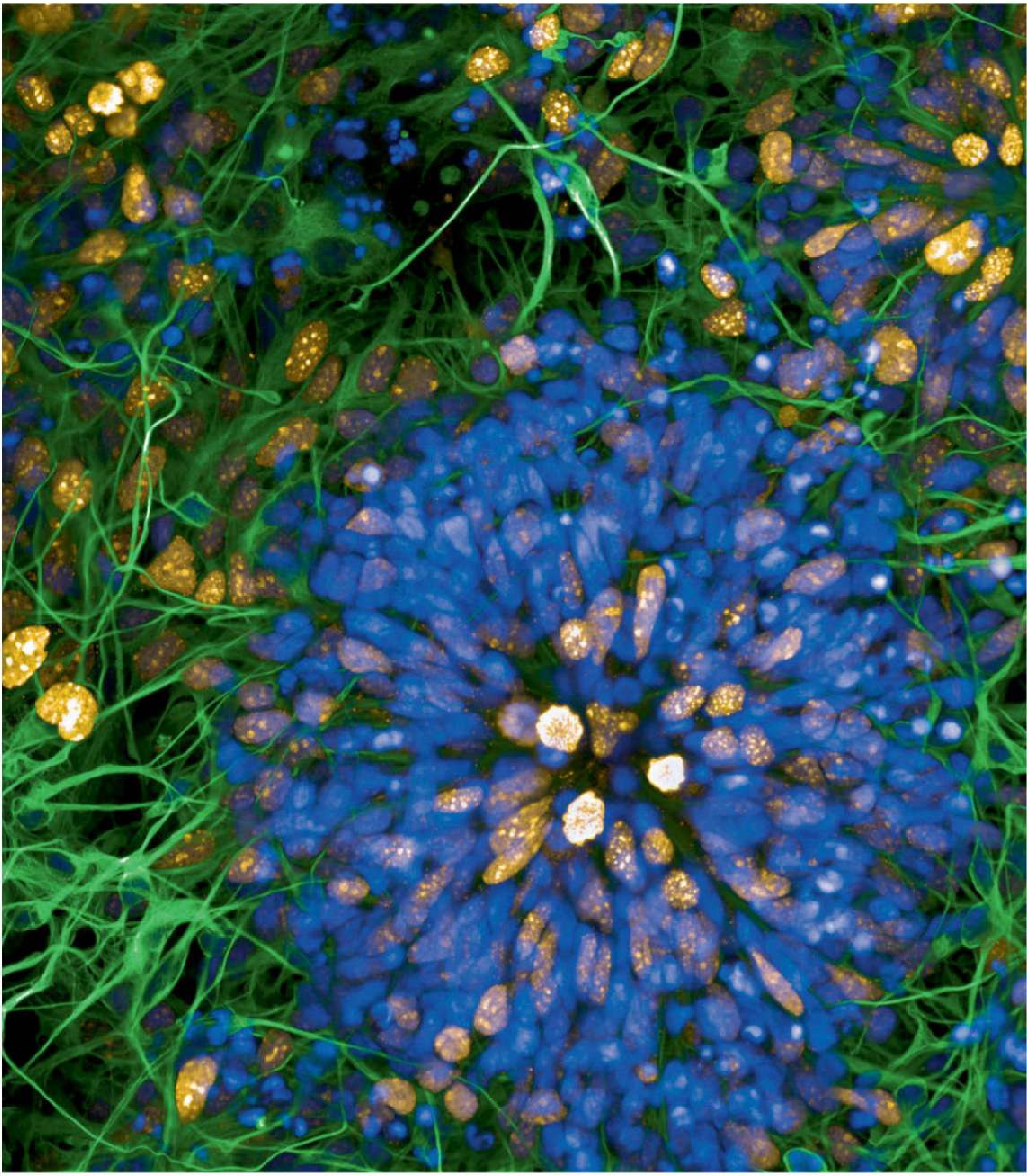

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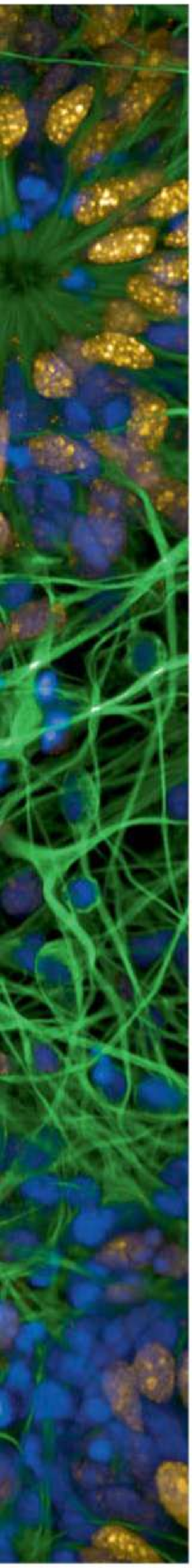

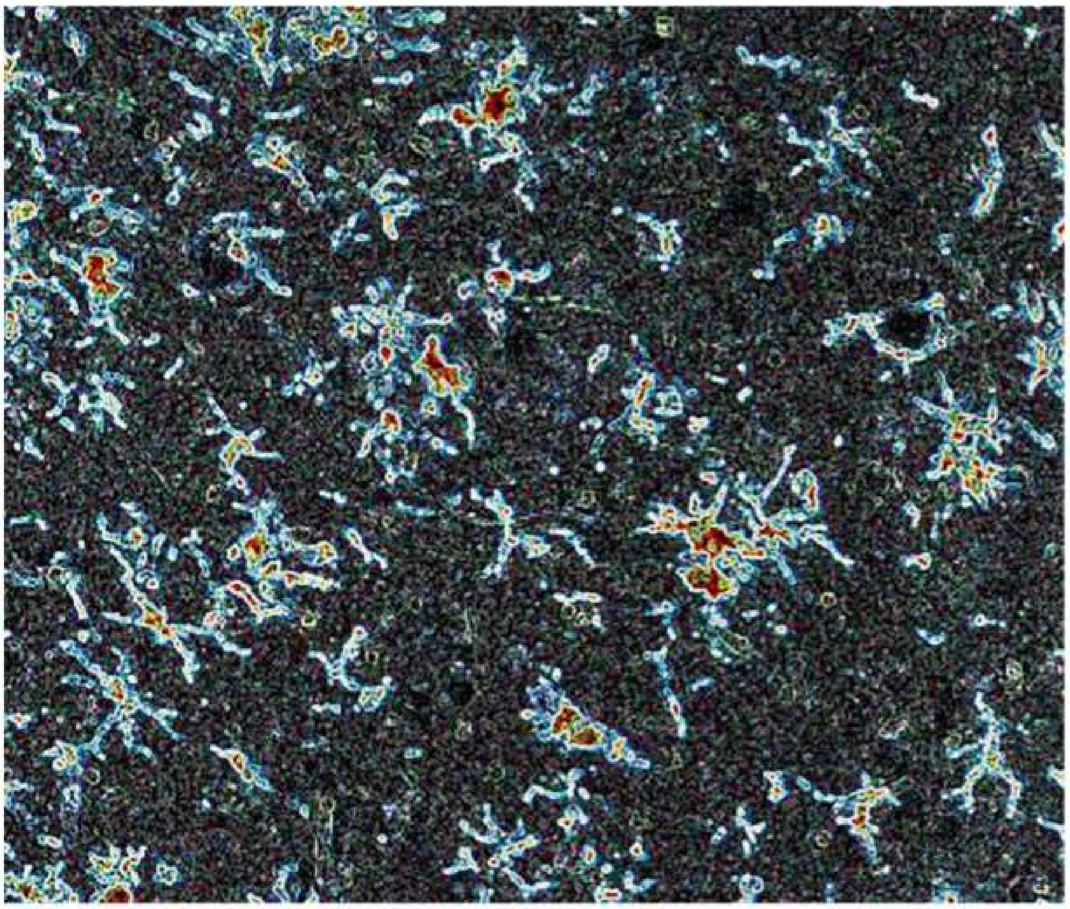

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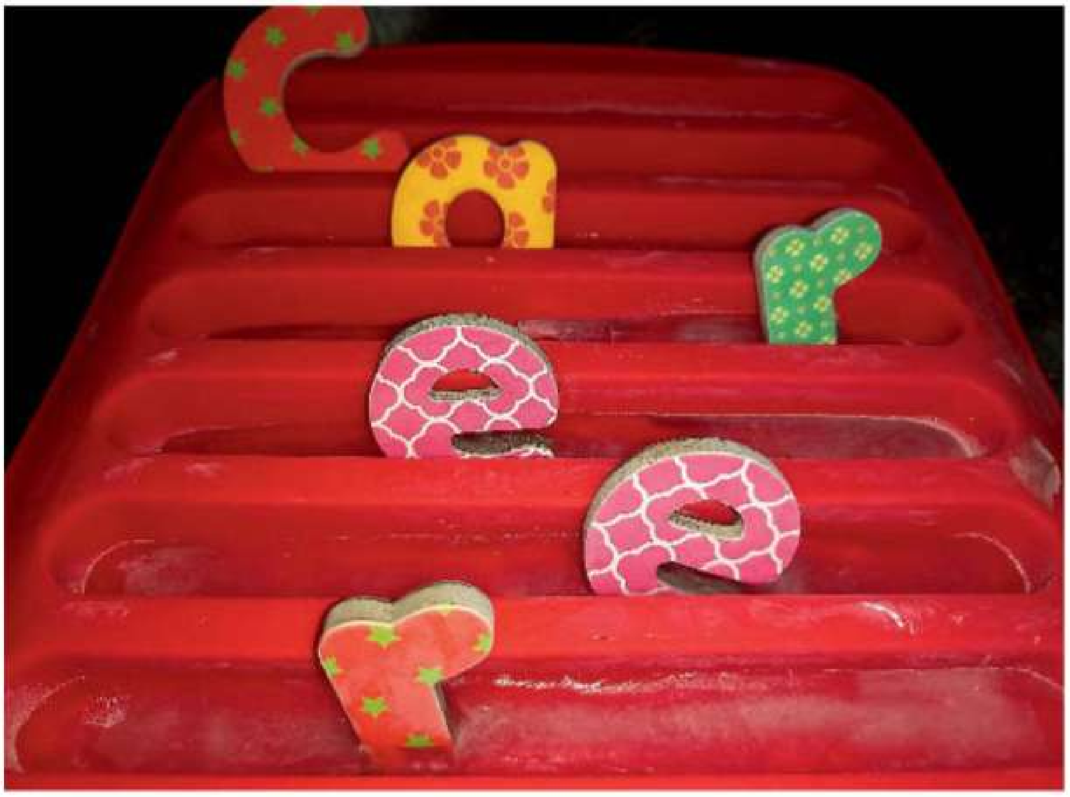

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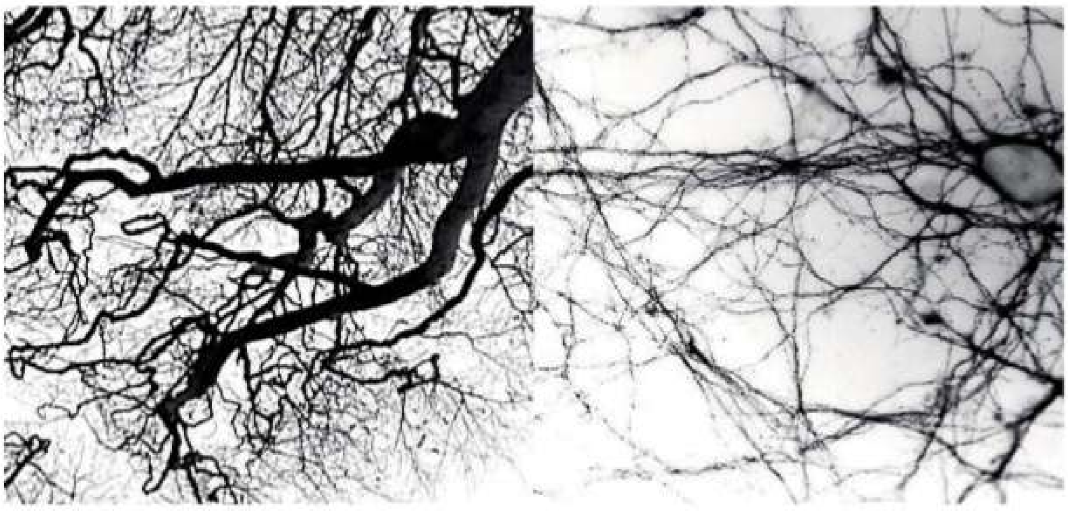


KIRSTEN WILLIAMSON, UNIVERSITY OF SOUTHAMPTON

Strange beauty

Spotlight on Dementia, Alzheimer's Society

THESE astonishing images show the unexpected beauty of research into dementia, a debilitating condition that affects around 57 million people globally. They are entrants in Spotlight on Dementia, a contest organised by the Alzheimer's Society, UK.

The aim is to challenge researchers to showcase their work as they explore everything from the impact of young-onset dementia to the potential involvement of the brain's immune system in the disease.

The winning picture (main image) was taken by Charlie Arber, based at University College London (UCL). His "Bed of Rosettes" shows a group of "blue" stem cells, called a neural rosette, as they start turning into "green" brain cells. Growing brain cells is vital for research into dementia.

In the adjoining column, the top image by Zeinab Abdi, also at UCL, shows donated microglia cells from a person with Alzheimer's. Microglia, a form of immune cell, help keep brains healthy, but they may also be involved in the early stages of the disease.

In the middle is an artistic commentary by Rachel Allen at the University of the West of Scotland on how dementia in younger people can lead to them being "frozen out" of their careers.

Last up is an entry by Kirsten Williamson at the University of Southampton, UK, emphasising the resemblance of tree branches (left) and a network of tau proteins (right), which malfunction in Alzheimer's disease. It is a reminder, she says, of the beauty of neuroscience.

Gege Li

Conscious creatures

Evidence that some animals dream helps to make the case that they have a sense of self, of "animalhood", finds **Simon Ings**

Book

When Animals Dream

David Peña-Guzmán

Princeton University Press

BLICKWINKEL/ALAMY

From dogs to penguins, many animals appear to dream when they sleep

HEIDI the octopus is dreaming. As she sleeps, her skin changes from smooth and white to flashing yellow and orange, then to deepest purple and, finally, to a series of greys and yellows, criss-crossed by ridges and spiky horns.

David Scheel, Heidi's human carer, has seen this pattern before in waking octopuses: Heidi, he says, is dreaming of catching and eating a crab.

The story of Heidi's dream, told in the 2019 documentary *Octopus: Making contact*, provides the starting point for a barnstorming new book, *When Animals Dream: The hidden world of animal consciousness* by David Peña-Guzmán.

A philosopher at San Francisco State University, Peña-Guzmán delivers an intellectual tour de force as he explores the extraordinary world of non-human imaginations.

The Roman philosopher-poet Lucretius thought that animals dreamed. So did Charles Darwin. The idea only lost respectability for about a century, roughly between 1880 to 1980, when the reflex was king and behaviourism ruled the psychology labs.

In the classical conditioning model developed by Ivan Pavlov, it is possible to argue that trained salivation at the sound of a bell is just a reflex. Later studies relied on a different method, called operant conditioning, in which a rat, say, has its behaviour reinforced either positively or negatively.

But none of these studies ever banished the notion that animals had imaginative interior lives. The experimenter can claim as much as they like that their trained rat is "conditioned", but that rat running through its maze looks for all the world as though it expects something.

> "By which paths did dreaming find its way into so many branches of the evolutionary tree?"

In fact, there is no "as though" about it. Peña-Guzmán, in a book rich in detail about experimental work, describes how rats, during their exploration of a maze, will dream up imaginary mazes and imaginary rewards – all of which is revealed by distinctive activity in their brains' hippocampi.

Evidence that animals have a kind of imagination is intriguing, but what really dragged the study of animal dreaming back into the light was a better understanding of how humans dream.

From the 1950s to the 1970s, dreams were seen as mere random activity in the pons, a part of the brainstem that links the brain to the spinal cord. Now we know that dreaming involves many more brain areas, including the parietal lobes, which are involved in the representation of physical spaces, and the frontal lobes, which are responsible for emotional regulation, among other things.

So which animals dream? Peña-Guzmán's list is long, but includes mice, dogs, belugas, platypuses, ostriches, penguins, chameleons, iguanas, cuttlefish and octopuses. "The jury is still out on crocodiles and turtles," he adds.

While the brain structures of these animals may be nothing like our own, studies of sleeping brains do expose startling commonalities, suggesting, perhaps, that dreaming is a skill upon which many branches of the evolutionary tree have converged.

Peña-Guzmán asks big questions. When did dreaming first emerge and why? By which paths did it find its way into so many branches of the evolutionary tree? And, perhaps the biggest question of all, what do we do with this information?

For him, dreams are morally significant because "they reveal animals to be both carriers and sources of moral value, which is to say, beings who matter and for whom things matter". In short, dreams may imply the existence of some sort of self.

The issue of whether or not that self can think rationally, act voluntarily or talk about its dreams, just like a human, is neither here nor there. The fact is, says Peña-Guzmán, animals that dream "have a phenomenally charged experience of the world… they sense, feel and perceive".

Starting from the tricky assertion that Heidi the octopus dreams of fresh crab suppers, Peña-Guzmán assembles strong evidence with which he makes a short, powerful, closely argued case for "animalhood". This book will change minds. ▮

Simon Ings is a writer based in London

Smell the roses

From cacao to vanilla, an unusual history connects aromatic molecules to human culture, discovers **Chris Stokel-Walker**

Book

Scent: A natural history of fragrance
Elise Vernon Pearlstine
Yale University Press

FOR countless people worldwide, their first inkling that they had covid-19 didn't come from a test, but from something far more visceral: anosmia, the loss of the ability to smell.

Our sense of smell, and our understanding of it, helps us to navigate the world, protecting us from harm and adding to the joy of living in equal measures. Catching a whiff of mercaptan, the eggy-smelling chemical added to natural gas supplies, can save you from a dangerous gas leak. And smelling the roses in an immaculate garden can lighten your mood enormously.

Yet putting into words what you can smell can be tricky for all sorts of reasons, not least because it is so subjective. But Elise Vernon Pearlstine, a wildlife biologist who changed careers to become a natural perfumer, manages it with aplomb. "Although we did not cause the rose to breathe out scent or the frankincense tree to shed fragrant tears, our stories are intertwined and mediated through the plant's secondary compounds that we call fragrance," she writes.

In *Scent*, Pearlstine's style suits the subject matter, relating the intricate, delicate details of each fragrance and the source of its smell. It is another investigation into scent, following Paola Totaro and Robert Wainwright's book *On the Scent* published earlier this year. But while their book concentrated on smell and its dysfunctions, Pearlstine's is more of a journey of discovery.

From outlining how frankincense functions as a protective resin that stops pathogens from invading wounded trees, to explaining how a tobacco plant's sweet-smelling benzylacetone lures in pollinators to ensure its survival, Pearlstine effortlessly unpacks a lifetime of knowledge. Meticulous information is shared through evocative writing to give you a passenger seat on a tour around the world's flora and fauna.

Along the way, we learn some unusual truths. Midges, the bane of summer life with their persistent bites, are vital to our supply of chocolate, acting as the main pollinator for cacao trees. Ghanaian cacao farmers have managed to supercharge their crop by planting banana and plantain trees nearby, both of which lure in more midges to fertilise the cacao flowers with the required 35 pollen grains.

The pollination of the cacao plant by midges turns from an interesting dinner party anecdote into macroeconomics, as Pearlstine explains that between 4 million and 10 million people worldwide are supported by the plant.

We also learn how big business has harnessed nature's powers. Less than 5 per cent of the vanilla flavour in our ice creams, cakes and cookies comes from the brown, wrinkled pods of the vanilla plant, with their jet-black beans. The rest is synthetic vanillin, produced using yeast or by blending chemicals. Vanilla was one of the first scents to be synthesised, says Pearlstine, as a by-product of wood pulp or rice.

And of course, as a perfumer, Pearlstine devotes later chapters to how we can capture, bottle and blend the best of nature's scents to make new, layered fragrances.

In rare moments, the torrent of information can wash over you too quickly, with dense paragraphs chock-full of facts and scientific terminology that muddles, rather than clarifies. When information overload combines with sometimes overwrought writing, it can take a second read to follow.

But those are the exceptions in this eminently readable book, which will leave you lingering a little longer among the roses – and the other smells that make our world what it is. ▮

Fragrances from plants such as roses help make established and new perfumes

OLIVER ROSSI/GETTY IMAGES

Chris Stokel-Walker is a technology writer based in Newcastle, UK

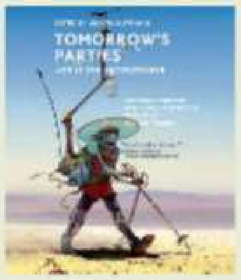
Don't miss

Visit

The Science of Psychedelics, and how to apply them to mental health conditions, is a focus for neuroscientist Maria Balaet. Hear her talk at the Lord Ashcroft Building, University of Cambridge, at 7pm BST on 22 August.

Watch

See, a dystopian fantasy set in a future where people have lost their sense of sight, returns for its third and final season. Created by screenwriter Steven Knight and starring Jason Momoa, you can catch it on Apple TV+ from 26 August.



Read

Tomorrow's Parties, edited by Jonathan Strahan, shows us life in the Anthropocene as climate change bites deeper. It features 10 short stories by the likes of Meg Elison and James Bradley. On sale from 23 August.

KOSTIANTYN FILICHKIN/GETTY IMAGES; ALAMY; APPLE TV

The games column

Live your best cat life Whether it's meowing or cuddling up with your furry companions, *Stray* is a great game if you fancy spending time as a feline, and looks set to become a classic for cat lovers, says **Jacob Aron**

Jacob Aron is *New Scientist*'s news editor. Follow him on Twitter @jjaron

Game

Stray

BlueTwelve Studio

PC, PlayStation 4 and 5

Jacob also recommends...

Games

Tokyo Jungle

Crispy's!

PlayStation 3

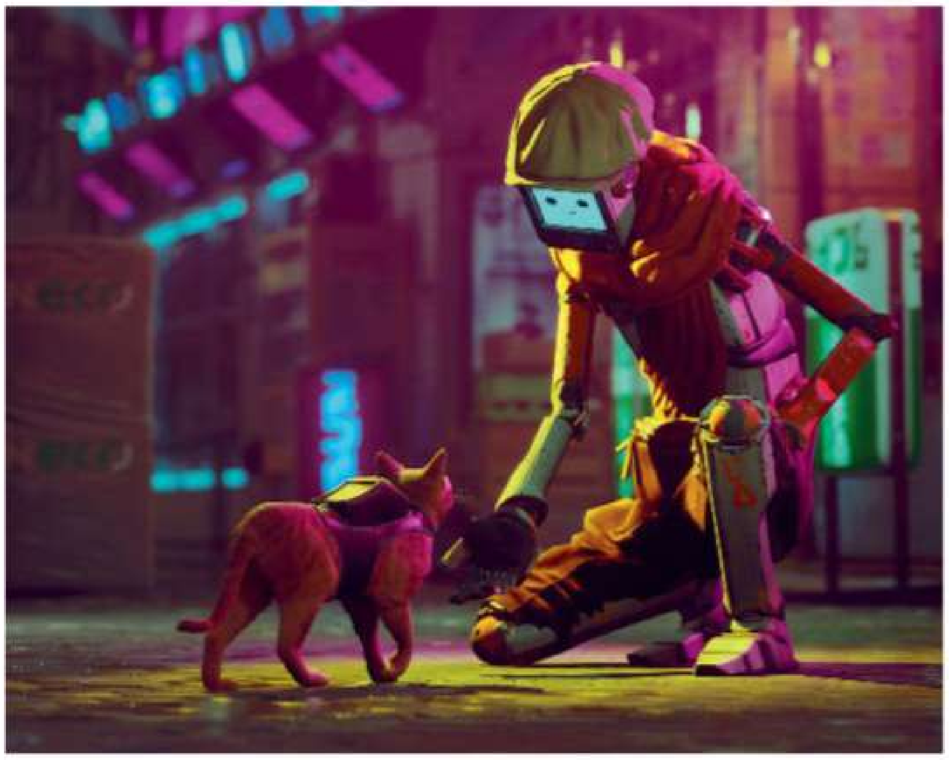
Set in the ruins of Tokyo, you start out playing as a Pomeranian dog, but can eventually switch to a variety of other animals, from giraffes to dinosaurs.

Goat Simulator

Coffee Stain Studios

PC, PlayStation 3 and 4, Xbox 360 and One, Nintendo Switch, Android, iOS

An absurd and bizarre game in which you run around as a goat, causing as much chaos as you possibly can. It is very, very far from being a realistic simulation of what life is like as a goat.



BLUETWELVE STUDIO

One of Dead City's humanoid robots – from the perspective of a cat

MY VIDEO game-playing career is littered with incarnations of the post-apocalypse, a setting that is such a cliché that I have probably explored the ruined wastelands of most US states in various guises. But I have never done it as a cat.

On the face of it, *Stray*'s premise – you are a cat trying to escape from an underground city populated by robots – sounds like a meme-worthy gimmick, but developer BlueTwelve Studio has done such a fantastic job of creating a realistic feline experience that it can't help but feel fresh and exciting.

When the game opens, your unnamed ginger cat is in an overgrown tunnel with three others, and the attention to detail is obvious as you play with and snuggle against your companions (anyone who has owned a cat will recognise these behaviours). From there, you begin running and jumping, getting a feel for navigating the world through the perspective of a cat, until you are separated from the others and end up in the ominously named Dead City.

After some more exploration and light puzzle-solving (the cat has a talent for lateral thinking, it seems), you meet a friendly drone called B-12 that decides to team up with you, equipping you with a backpack to keep it charged. The moment the cat puts on the backpack is incredible – walking slowly with an arched spine and sullen demeanour, it looks exactly like it has had some anti-flea medicine coated on its fur and couldn't be more angry.

> **"I actively found myself role-playing as a cat, seeking out places to curl up and snooze, or objects to bat about"**

Once the cat settles down, you find that B-12 can help you speak to the various humanoid robots that inhabit Dead City. From here, the game is ostensibly a mix of exploring and fetching items to help you unlock the next level, but really it is just a game about being a cat.

Whether it is pushing objects off ledges with a tap of your paws, scratching against a door and demanding to be let in or even just hammering the dedicated "meow" button (which serves almost no gameplay purpose, but is a joy to use), *Stray* gives you every opportunity to live your best cat life. I actively found myself role-playing as a cat, seeking out places to curl up and snooze, or objects to bat about.

BlueTwelve Studio seems to have fully understood that letting players occupy the cat mindset is as important, if not more important, than the fairly routine story it is trying to tell.

The only way *Stray* disappoints is by having strange, blobby creatures called Zurks pursue you in various sequences throughout the game – distressingly, they can attach to the cat with suckers and kill it, though thankfully you can just reload the game.

Sure, these creatures help build out the world, apparently the result of bacteria gone wrong, but from a gameplay perspective it smacks of a developer panicking and adding enemies to a game that really doesn't need them. The low point of *Stray* is a level in which B-12 is equipped with a UV light that can destroy Zurks, temporarily turning it into a frustrating and dull shooter.

The game is short, only taking me 5 hours or so to finish, but that just means it doesn't have a chance to outstay its welcome. On PC, fans are already adding the ability to transform the cat into a breed of your choice, or even into a famous cat like Garfield, so I think that *Stray* is destined to become a cult classic among cat-lovers – and rightly so. ▮

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‘Revel in being a work in progress’: Top scientists reflect on their time at university

With students across the UK getting their exam results and many making life-changing decisions about where and what to study, we asked stars of the upcoming New Scientist Live show about their time at uni and what advice they would give to the next generation

RIA MISHAAL PHOTOGRAPHY

As one might imagine, many of our New Scientist Live speakers headed to university to study a scientific subject, but some found their way onto our show via a more circuitous route. Science writer Emma Byrne, who will be speaking about the brain at our October show, was persuaded by “incredibly sexist career advice” to study business and modern languages, only later specialising in science via a PhD in artificial intelligence. She says that “if you’re going to university in your late teens or early 20s, you’re going at a time of amazing brain plasticity. Try as many new things as possible – revel in being a work in progress.”

Some of our speakers went to university with a clear idea of what they were going to study, only to be inspired by a different area of science after they arrived. Immunologist Dan Davis says: “I studied physics because I thought that the laws which work across the whole universe must be the most important and fundamental thing to study. But later in my career, I changed my mind. I decided that life – even if it’s just a local thing – is actually even more important to me.”

Psychologist Pete Etchells had a similar journey. After being persuaded that technology was the future, he had a terrible time studying computer science at Bristol, before switching to psychology. His advice for psychology students is that most courses will be accredited with the British Psychological Society and will have roughly the same content, so prioritise finding a location that feels like home, as Bristol did for him. Geologist Chris Jackson has similar

> “Your university years are when you have the chance to have a go at almost anything you could possibly imagine”
>
> **Helen Scales**
> Writer, broadcaster and marine biologist

“Manchester was always my first choice. It was cheaper to live in than London, had amazing nightlife and only required three Cs!”

Chris Jackson
Geoscientist at scientific
consultancy Jacobs

“Be sure to ring fence time for your own well-being”

Simon Clark
Film-maker and
science communicator

advice, having chosen Manchester for both the course and the amazing music scene. He says prospective students should think about how they will fit in beyond the confines of their chosen institution, as they will need social and cultural support.

Astrophysicist Emma Osborne, who will be speaking about gravitational waves at New Scientist Live, says she would have studied fashion and textiles if she could have her time over. In a similar fashion, marine biologist Helen Scales can see herself having gone down an entirely different path had she studied her second choice of art, whereas mathematician Junaid Mubeen could have ended up as a lawyer had he chosen differently. What is clear is that many of the top scientists appearing at the show have maintained wider interests outside of STEM, like physicist Simon Clark, who says he would study history or film if he had his time again.

Many speakers advise new students, whatever they study, to just get stuck in. Medical researcher Blair Merrick puts it this way: “Work hard and play hard.” Scales is of the same opinion: “Your university years are when you have the chance to have a go at almost anything you could possibly imagine.”

Others caution against feeling too much pressure. Clark stresses the importance of time away from studies: “Be sure to ring fence time for your own well-being and for extracurricular activities.” Science writer Kat Arney, who will be revealing a new view of cancer at the show, cautions against assuming that everyone is way cooler and having a much better time than you are. She notes that if you are doing a science subject, it will be hard and you won’t have time for everything, but that’s fine.

Arney also says that, at any UK university, you are likely to be taught by some world-leading experts in their field, which she feels she didn’t appreciate at the time. This is a view shared by Patrick Vallance, chief scientific adviser to the UK government, who will also be at our show. “Try to make sure you get taught by people who are active researchers,” he says. “There is something about being taught by someone who is pushing back the boundaries of knowledge that I think is really important.”

Don’t miss out on New Scientist Live at ExCeL London from 7-9 October 2022. Go to live.newscientist.com for your early bird tickets

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Views Your letters

Editor's pick

How to cope with darker side of daydreaming

30 July, p 46

From Paul Mealing, Melbourne, Australia

Eric Taipale's report "The dark side of daydreaming" resonated with me. I spent a lot of my childhood in an inner world – I often drew and even wrote scripts and created my own superheroes. Decades later, I started writing fiction, which I would suggest is a healthy outlet. For me, it was a psychological necessity. I still write fiction and don't care if no one reads it.

Alison Leonard, Hebden Bridge, West Yorkshire, UK

As a lifelong daydreamer who has channelled those daydreams into therapeutic and sometimes lucrative creativity, I would like to discourage yet another rush towards medicalised labelling.

If "maladaptive" daydreaming is commonest in children who are traumatised, lonely, distressed or bored, as Taipale suggests, then surely the cure isn't to discourage creative ways of coping, but to change the child-rearing practices that give rise to these problems.

From Donald Windsor, Norwich, New York, US

Daydreaming is what writers routinely do. We dream up stories and put them into print. Perhaps those who think their daydreaming is maladaptive should take up writing.

Welcome to the corporate family

23 July, p 27

From Sam Edge, Ringwood, Hampshire, UK

Jonathan R. Goodman's article about corporate psychology really hit a nerve with me. I once had a brief stint working for a well-known, family-owned company. Almost the first thing I was told when I joined them was that it is a "family business" and that the staff are supposed to think of themselves as part of the family. This was reiterated on posters and in internal newsletters.

Ironically, it was one of the most corporate firms I have worked for, with very inflexible working practices and bureaucracy.

Little hope of backing for climate info campaign

6 August, p 29

From Denis Watkins, St Just in Roseland, Cornwall, UK

Bill McGuire wants a public information campaign to trigger action on the climate emergency. In the absence of political concern, daily life continues unabated. So, people fly abroad on holidays, the government seeks to expand the economy and fossil fuel firms are able to behave as before.

With no leadership from our politicians, the reality of the climate catastrophe isn't seen. What political support can those who share McGuire's views expect?

Reasons why the Higgs field is no ether

Letters, 30 July

From Ian Dunbar, Culcheth, Cheshire, UK

David Werdegar asks whether the Higgs field is like the luminiferous ether. The answer is no.

According to quantum field theory, fields, like the Higgs field and the electromagnetic field, are fundamental dynamical systems. The things we perceive as particles are excitations of these systems and couplings between fields correspond to interactions between particles. We exist at the level of the particles, and all we know of fields comes from our interactions with other particles.

When enough particles get together – in the air, for example – these systems can have their own excitations, sound waves in this case, that constitute a third level. The ether was meant to be a system at the same level as air, and light an excitation at the same level as sound. These were shown not to exist, but that doesn't rule out an electromagnetic field at the first level. Indeed, all we know about elementary particles suggests they are field excitations. To conflate the Higgs field (level one) with the ether (level two) is a category error.

AI must try to crack another ancient script

6 August, p 40

From Maureen Clayson, Stratford-upon-Avon, Warwickshire, UK

I found the article "Cracking the code", on the use of AI to read the ancient Mesopotamian script cuneiform, extremely interesting. It has got me wondering if such AI could be used, or perhaps is being used, to crack Linear A, the undeciphered ancient script of the Minoans of Crete? What a triumph it would be to finally translate that.

Will an engineered-protein revolution be good for us?

6 August, p 10

From Alec Williams, Whitehead, County Antrim, UK

Your coverage of the AlphaFold AI and its ability to predict protein structures mentioned that it had been used to engineer enzymes that could break down plastic waste. I fear this application.

Presumably, such enzymes could be incorporated into microorganisms and released into the sea. Would they know the difference between a crisp packet and a plastic boat or the plastic covering of undersea cables? Can you imagine the effect of eating a hole in a naval minesweeper?

These organisms might evolve to enter soil and munch on gas pipes. And what if they were to enter a person's bloodstream and gobble on stents or other inserted medical devices?

So true that BMI is a poor measure of bodily health

Letters, 30 July

From Rachel Cave, Bundoran, County Donegal, Ireland

I was taken by the letters on diet, in particular the one from Greg Harris on the poor relationship between body mass index (BMI) and health.

If we could list the BMI of all athletes at the Commonwealth Games in the UK, it would be very revealing on this point, showing what a poor measure of obesity BMI is when used without any consideration of other factors.

Ditch the lawn and grow other stuff instead

30 July, p 28

From Talia Morris, Cape Tribulation, Queensland, Australia

On Beronda L. Montgomery's search for an eco-friendly lawn, the truth about lawns is that their environmental impact is neutral at best. As she says, better to grow trees or local native vegetation than to have a sterile-looking patch of grass. ■

For the record

▌Our story on woodpecker skulls was accompanied by a photo of a female pileated woodpecker (23 July, p 19).

▌In our look at deciphering cuneiform script, the Babylonian god we mentioned is Marduk (6 August, p 40).

▌The image on the first page of our take on mosquito-borne diseases in Rio de Janeiro was of the favela complex Rocinha (6 August, p 48).

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, Northcliffe House, 2 Derry Street, London W8 5TT will be delayed

Reality's hidden depths

Translating our theories of physics into an eight-dimensional number system might just give us a way to make sense of the laws of nature, says **Michael Brooks**

WORDS can be slippery. That is perhaps even more true in physics than it is in the rest of life. Think of a "particle", for instance, and we might conjure an image of a tiny sphere. In truth, "particle" is just a poetic term for something far removed from our everyday experience – which is why our best descriptions of reality make use of the cold precision of mathematics.

But just as there are many human languages, so there is more than one type of number system. Most of us deal with only the familiar number line that begins 1, 2, 3. But other, more exotic systems are available. Recently, physicists have been asking a profound question: what if we are trying to describe reality with the wrong type of numbers?

Each mathematical system has its own special disposition, just like languages. Love poems sound better in French. German has that knack of expressing sophisticated concepts – like schadenfreude – in a few syllables. Now, in the wake of a fresh breakthrough revealing tantalising connections between models of how matter works at different energy scales, it seems increasingly likely that an exotic set of numbers known as the octonions might have what it takes to capture the truth about reality.

Mathematicians are excited because they reckon that by translating our theories of reality into the language of the octonions, it could tidy up some of the deepest problems in physics and clear a path to a "grand unified theory" that can describe the universe in one statement. "This feels like a very promising direction," says Latham Boyle at the Perimeter Institute in Waterloo, Canada. "I find it irresistible to think about."

Many physicists dream of finding a grand unified theory, a single mathematical framework that tells us where the forces of nature come from and how they act on matter. Critically, such a theory would also capture how and why these properties changed over the life of the universe, as we know they have.

So far, the closest we have come is the standard model of particle physics, which details the universe's fundamental particles and forces: electrons, quarks, photons and the rest. The trouble is, the standard model has its shortcomings. To make it work, we must feed in around 20 measured numbers, such as the masses of particles. We don't know why these numbers are what they are. Worse, the standard model has little to say about space-time, the canvas in which particles live. We seem to live in a four-dimensional space-time, but the standard model doesn't specify that this must be so. "Why not, say, seven-dimensional space-time?" Boyle wonders.

Imaginary numbers

Many think the solution to these woes will come when experiments uncover a missing piece of the standard model. But after years of effort, this hasn't happened, and some are wondering if the problem is the maths itself.

Mathematicians have known for centuries that there are numbers other than the ones we can count on our fingers. Take the square root of -1, known as *i*. There is no meaningful answer to this expression, as both 1 × 1 and -1 × -1 are equal to 1, so *i* is an "imaginary number". They found that by combining *i* with real numbers – which include all the numbers you could place on a number line, including negative numbers and decimals – they could fashion a new system called the complex numbers.

Think of complex numbers as being two-dimensional; the two parts of each number can record unrelated properties of the same object. This turns out to be extremely handy. All our electronic infrastructure relies on complex numbers. And quantum theory, our hugely successful description of the small-scale world, doesn't work without them.

In 1843, Irish mathematician William Rowan Hamilton took things a step further. Supplementing the real and the imaginary numbers with two more sets of imaginary numbers called *j* and *k*, he gave us the quaternions, a set of four-dimensional numbers. Within a few months, Hamilton's friend John Graves had found another system with eight dimensions called the octonions.

Real numbers, complex numbers, quarternions and octonions are collectively known as the normed division algebras. They are the only sets of numbers with which you can perform addition, subtraction, multiplication and division. Wilder systems are possible – the 16-dimensional sedenions, for example – but here the normal rules break down.

Today, physics makes prolific use of three of these systems. The real numbers are ubiquitous. Complex numbers are essential in particle physics as well as quantum physics. The mathematical structure of general relativity, Albert Einstein's theory of gravity, can be expressed elegantly by the quaternions.

The octonions stand oddly apart as the only system not to tie in with a central physical law. But why would nature map onto only three of these four number systems? "This makes one suspect that the octonions – the grandest and

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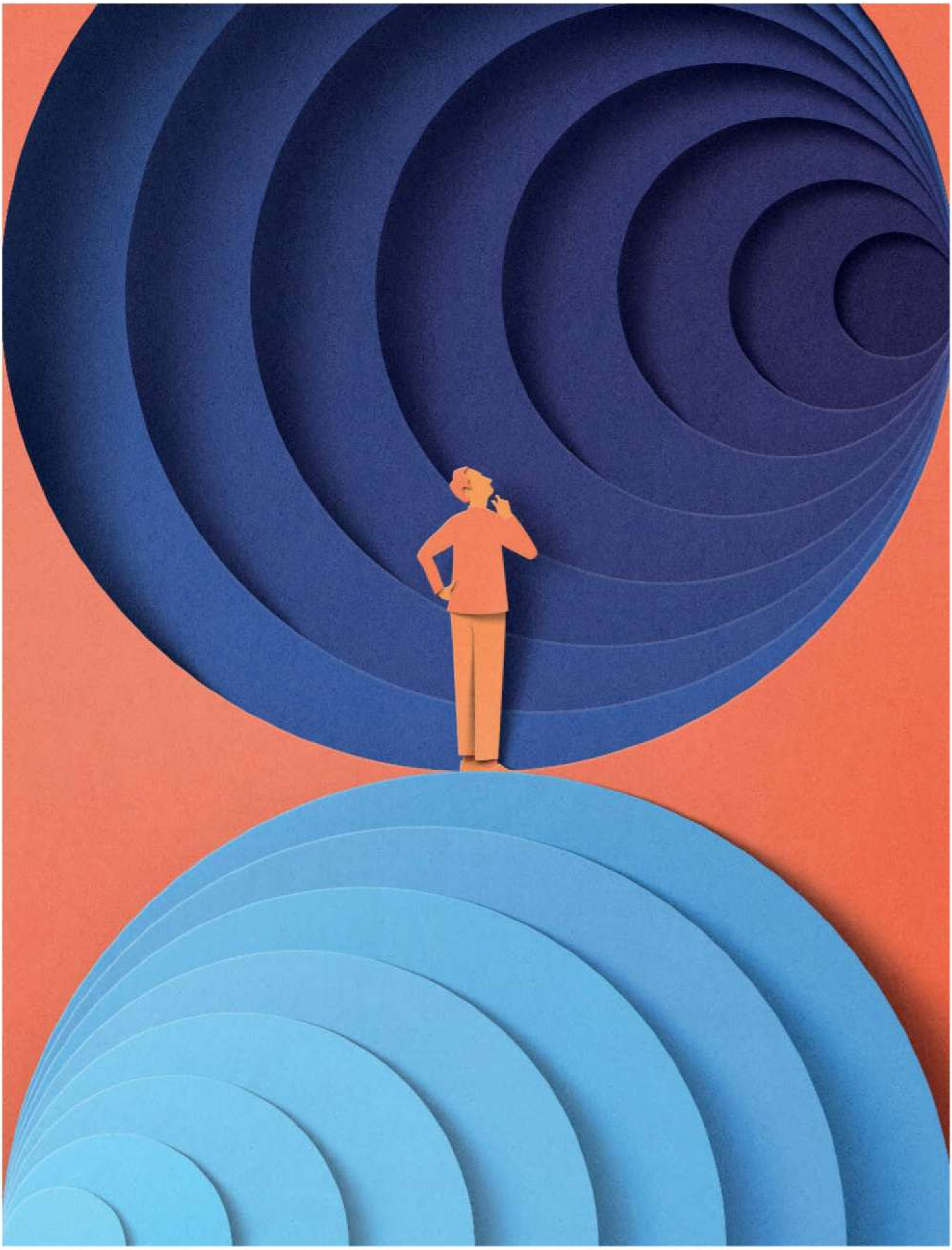

EIKO OJALA

Exotic numbers could reveal where reality comes from

> “Many have tried and failed to decipher the octonions’ role in reality”

least understood of the four – should turn out to be important too,” says Boyle.

In truth, physicists have been thinking such thoughts since the 1970s, but the octonions have yet to fulfil their promise. Michael Duff at Imperial College London was, and still is, drawn to the octonions, but he knows many have tried and failed to decipher their role in describing reality. “The octonions became known as the graveyard of theoretical physics,” he says.

That hasn’t put off a new generation of octonion wranglers, including Nichol Furey at Humboldt University of Berlin. She likes to look at questions in physics without making any assumptions. “I try to solve problems right from scratch,” she says. “In doing so, you can often find alternate paths that earlier authors may have missed.” Now, it seems she and others might be making the beginnings of an octonion breakthrough.

Russian dolls

To get to grips with Furey’s work, it helps to understand a concept in physics called internal symmetry. This isn’t the same as the rotational or reflectional symmetry of a snowflake. Instead, it refers to a number of more abstract properties, such as the character of certain forces and the relationships between fundamental particles. All these particles are defined by a series of quantum numbers – their mass, charge and a quantum property called spin, for instance. If a particle transforms into another particle – an electron becoming a neutrino, say – some of those numbers will change while others won’t. These symmetries define the structure of the standard model.

Internal symmetries are central to the quest for a grand unified theory. Physicists have already found various mathematical models that might explain how reality worked back at the time when the universe had much more energy. At these higher energies, it is thought there would have been more symmetries, meaning that some forces we now experience as distinct would have been one and the same. None of these models have managed to rope gravity into the fold: that would require an even grander “theory of everything”. But they do show, for instance, that the electromagnetic force and weak nuclear force would have been one “electroweak” force until a fraction of a second after the big bang. As the universe cooled, some of the symmetries broke, meaning this particular model would no longer apply. Each different epoch requires a different mathematical model with a gradually reducing number of symmetries. In a sense, these models all contain each other, like a set of Russian dolls.

One of the most popular candidates for the outermost doll – the grand unified theory that contains all the others – is known as the spin(10) model. It has a whopping 45 symmetries. In one formulation, inside this sits the Pati-Salam model, with 21 symmetries. Then comes the left-right symmetric model, with 15 symmetries, including one known as parity, the kind of left-right symmetry that we encounter when we look in a mirror. Finally, we reach the standard model, with 12 symmetries. The reason we study each of these models is that they work; their symmetries are consistent with experimental evidence. But we have never understood what determines which symmetries fall away at each stage.

In August 2022, Furey, together with Mia Hughes at Imperial College London, showed for the first time that the division algebras, including the octonions, could provide this link. To do so, they drew on ideas Furey had years ago to translate all the mathematical symmetries and particle descriptions of various models into the language of division algebras. “It took a long time,” says Furey.

The task required using the Dixon algebra, a set of numbers that allow you to combine real, complex, quaternion and octonion maths. The result was a system that describes a set of octonions specified by quaternions, which are in turn specified by complex numbers that are specified by a set of real numbers. “It’s a fairly crazy beast,” says Hughes.

It is a powerful beast, too. The new formulation exposed an intriguing characteristic of the Russian doll layers. When some numbers involved in the complex, quaternion and octonion formulations are swapped from positive to negative, or vice versa, some of the symmetries change and some don’t. Only the ones that don’t are found in the next layer down. “It allowed us to see connections between these well-studied particle models that had not been picked up on before,” says Furey. This “division algebraic reflection”, as Furey calls it, could be dictating what we encounter in the real physical

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> **"Strange maths could be our best route to making sense of the laws of nature"**

universe, and – perhaps – showing us the symmetry-breaking road up to the long-sought grand unified theory.

The result is new, and Furey and Hughes haven't yet been able to see where it may lead. "It hints that there might be some physical symmetry-breaking process that somehow depends upon these division algebraic reflections, but so far the nature of that process is fairly mysterious," says Hughes.

Furey says the result might have implications for experiments. "We are currently investigating whether the division algebras are telling us what can and cannot be directly measured at different energy scales," she says. It is a work in progress, but analysis of the reflections seems to suggest that there are certain sets of measurements that physicists should be able to make on particles at low energies – such as the measurement of an electron's spin – and certain things that won't be measurable, such as the colour charge of quarks.

Among those who work on octonions, the research is making waves. Duff says that trying to fit the standard model into octonionic language is a relatively new approach: "If it paid off, it would be very significant, so it's worth trying." Corinne Manogue at Oregon State University has worked with octonions for decades and has seen interest ebb and flow. "This moment does seem to be a relative high," she says, "primarily, I think, because of Furey's strong reputation and advocacy."

The insights from the octonions don't stop there. Boyle has been toying with another bit of exotic maths called the "exceptional Jordan algebra", which was invented by German physicist Pascual Jordan in the 1930s. Working with two other luminaries of quantum theory, Eugene Wigner and John von Neumann, Jordan found a set of mathematical properties of quantum theory that resisted classification and were closely related to the octonions.

Probe this exceptional Jordan algebra deeply enough and you will find it contains the mathematical structure that we use to describe Einstein's four-dimensional space-time. What's more, we have known for decades that within the exceptional Jordan algebra, you will find a peculiar mathematical structure that we derived through an entirely separate route and process in the early 1970s to describe the standard model's particles and forces. In other words, this is an octonionic link between our theories of space, time, gravity and quantum theory. "I think this is a very striking, intriguing and suggestive observation," says Boyle.

Responding to this, Boyle has dug deeper and discovered something intriguing about the way a class of particles called fermions, which includes common particles like electrons and quarks, fits into the octonion-based language. Fermions are "chiral", meaning their mirror-image reflections – the symmetry physicists call parity – look different. This had created a problem when incorporating fermions into the octonion-based versions of the standard model. But Boyle has now found a way to fix that – and it has a fascinating spin-off. Restoring the mirror symmetry that is broken in the standard model also enables octonionic fermions to sit comfortably in the left-right symmetric model, one level further up towards the grand unified theory.

In particle physics, models can contain each other like a set of Russian dolls

SHUTTERSTOCK/ATLANTIST STUDIO

Beyond the big bang

This line of thinking might even take us beyond the grand unified theory, towards an explanation of where the universe came from. Boyle has been working with Neil Turok, his colleague at the Perimeter Institute, on what they call a "two-sheeted universe" that involves a set of symmetries known as charge, parity and time (CPT). "In this hypothesis, the big bang is a kind of mirror separating our half of the universe from its CPT mirror image on the other side of the bang," says Boyle. The octonionic properties of fermions that sit in the left-right symmetric model are relevant in developing a coherent theory for this universe, it turns out. "I suspect that combining the octonionic picture with the two-sheeted picture of the cosmos is a further step in the direction of finding the right mathematical framework for describing nature," says Boyle.

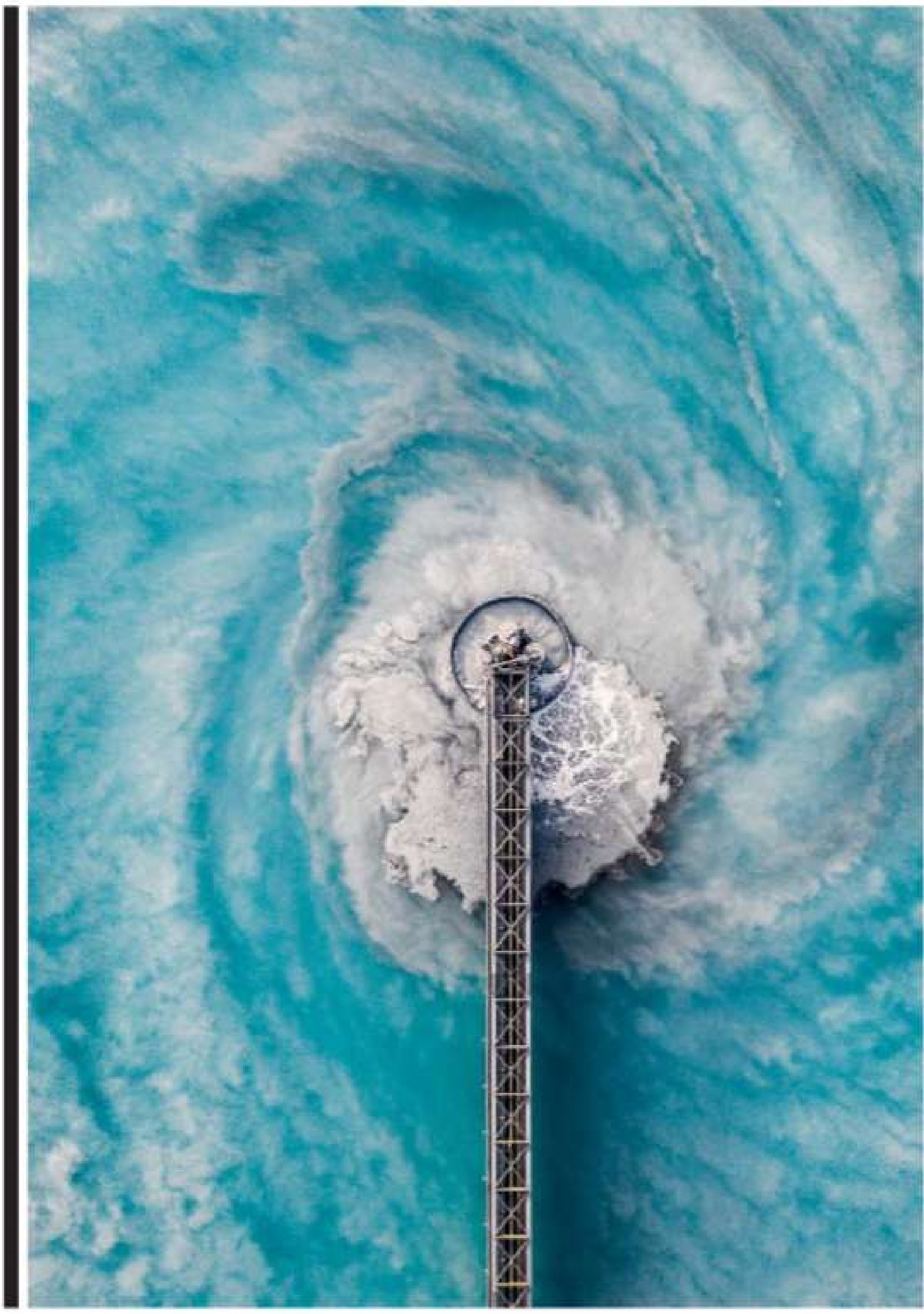
As with all the discoveries linking the octonions to our theories of physics so far, Boyle's work is only suggestive. No one has yet created a fully fledged theory of physics based on octonions that makes new predictions we can test by using particle colliders, say. "There's still nothing concrete yet: there's nothing we can tell the experimentalists to go and look for," says Duff. Furey agrees: "It is important to say that we are nowhere near being finished."

But Boyle, Furey, Hughes and many others are increasingly absorbed by the possibility that this strange maths really could be our best route to understanding where the laws of nature come from. In fact, Boyle thinks that the octonion-based approach could be just as fruitful as doing new experiments to find new particles. "Most people are imagining that the next bit of progress will be from some new pieces being dropped onto the table," he says. "That would be great, but maybe we have not yet finished the process of fitting the current pieces together." ▮

Michael Brooks is a *New Scientist* consultant and author of *The Art of More: How mathematics created civilisation*

Secrets in the sewers

Waste water from human communities is a mine of information on our health, well-being and inequality. At last, its potential is being tapped, finds **Claire Ainsworth**



The countless chemicals and pathogens that you flush away end up in your nearest sewage treatment plant

"WHAT'S the largest source of mass moving in and out of a city every day? You think, if it's a port city, it must be boats – or, you know, maybe if it's a landlocked city, it's trains or trucks or cars or planes. No, it's water. It's water. There's so much more water moving in and out of a city any day than there is any kind of cargo. It's basically pure water coming in. And then the water that leaves has some traces of almost every human activity that's going on in the city."

Once Eric Alm is in full flow, it is hard to stop him. But it isn't hard to understand his enthusiasm. Alm, a biological engineer at the Massachusetts Institute of Technology, is one of a growing band of researchers turning their attention to the fluid coursing through our sewers. This waste water, as it is known, contains the whispered biochemical confessions of millions of people, and by listening to them, scientists can paint surprisingly detailed pictures of our health, wealth and environment, head off epidemics, track pandemics and even spot new "designer" drugs before their effects show up in the population.

The field, called waste water-based epidemiology, not only has the potential to revolutionise public health but also transform our view of sewage from disgusting waste to something incredibly valuable. "You can think of the city as one big organism," says Rolf Halden at Arizona State University, another convert to the study of waste water. "It has one metabolism." And that makes sewage the lifeblood of our communities.

You might think that what happens in the smallest room of the house is strictly between you and the porcelain. But once you flush, the products of your privy quickly become public. They take the downpipe into the drain and then to the sewer, where they coil and coalesce with those of your neighbours, your neighbours' neighbours and so on, before ending up at the local treatment plant as what is effectively a pee and poo sample for the whole sewage catchment area.

The idea that this might contain useful information was first suggested a couple of decades ago. In 2005, a landmark study took samples from the river Po in Italy, whose

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L: ABSTRACT AERIAL ART/GETTY IMAGES RIGHT: COMEZORA/GETTY IMAGES; PETER BAKER/GETTY IMAGES

What waste water reveals depends on whether it comes from a sewage works or beneath a manhole

> “Everything changed in late 2019, with reports of a sinister new virus”

catchment includes waste water from 5 million people. Researchers tested the samples for cocaine and its principal metabolite, benzoylecgonine – the main compound the body breaks it down into. This revealed that the river was carrying the waste that would be produced by consumption of 4 kilograms of cocaine each day, which translates into around 40,000 separate uses of the drug. Previous estimates had put consumption at 15,000 hits. The work inspired scientists across Europe to standardise the collection and analysis of information about drugs in waste water and establish a continent-wide monitoring system.

Halden heard about these developments from colleagues in Europe and, in the early 2000s, began to apply the approach in the US. He and his team collected waste water samples from across the country and stored them as an archive, originally dubbed the National Sewage Sludge Center, but soon changed to the Human Health Observatory. It wasn’t well received. “There was just tremendous resistance to even accepting that there could be useful information in composited waste water,” he says. However, the approach was vindicated when the team showed that two antimicrobial compounds called triclocarban and triclosan – commonly added to soaps and other consumer products – persist in sewage for much longer than previously thought. They were known to be harmful to humans and the environment, and the finding ultimately led to them being prohibited in consumer products in the US. Bans further afield followed.

Despite such early successes, for years, many waste water-based epidemiologists struggled to get funding and recognition. That changed in late 2019, when reports of a sinister new respiratory illness emerged from China. Scientists realised that the virus responsible, SARS-CoV-2, could be spotted in sewage. They could detect low levels of the virus in waste water samples, revealing where it was spreading days before people began showing up at hospitals, allowing health authorities to direct their resources accordingly. What’s more, Halden calculated that tracking the virus in this way was about 60 times cheaper than using clinical testing.

Public health authorities soon caught on. The US Centers for Disease Control launched a national waste water surveillance system in 2020, and has awarded grants totalling approximately $220 million to projects monitoring SARS-CoV-2 in this way. In the US and in other countries, this has been instrumental in helping authorities stay one step ahead of the pandemic. “That’s really where the dam broke and a lot of people began to become believers and practitioners of the technology,” says Halden.

The power of this approach to track diseases became apparent in February 2022, when sewage monitoring detected an outbreak of polio in London, UK, before any clinical cases appeared. Based on these detections, booster vaccines will soon be offered to children in the city. But monitoring such as this only touches the surface of what waste water epidemiology could do. In principle, it can detect almost anything in sewage, from markers of diet and stress to prescription drugs and personal care products. It is even possible to determine whether a compound has been through a human body or not, because the liver adds a chemical tag to anything passing through it. “The sky’s the limit,” says Halden.

What is possible partly depends on where the samples are taken. All sewage ends up at a treatment plant, also called the sewage works. Sampling here allows you to look at a lot of people, which means that you can get a good overall picture of how the general population is exposed to a chemical or infectious agent of interest. On the other hand, because sewage has travelled a long way and ›

EFFLUENT ETHICS

Analysing samples of sewage may not seem like an ethical minefield. In flushing the toilet, don't we abandon our waste in the same way we do when we dump our rubbish in landfill? Besides, it isn't possible to identify an individual from the myriad chemical traces that turn up at the sewage works.

Not so fast, say Natalie Ram, a privacy law scholar at the University of Maryland. Waste water monitoring of large populations may not be too problematic, but when scientists sample smaller populations, thorny ethical issues can arise.

Highlighting high levels of illegal drug use or disease in a neighbourhood could lead to that community becoming stigmatised, says Ram, a particular problem in countries like the US where postcodes are heavily segregated along socioeconomic and racial lines.

It also raises the issue of personal privacy: as the size of the population being sampled shrinks, so the possibility of someone being identified from substances in waste water grows, especially if the sewerage data is cross-referenced with information from other sources, she says.

This certainly isn't what the scientists who study waste water epidemiology have in mind. Many are acutely aware of the issues and have drawn up ethical guidelines, and undertake public consultations to ensure the technology is put to proper use.

Nevertheless, the lack of a legal framework is a real problem. "Most technology tools ultimately get turned to law enforcement purposes," says Ram. "That's why I think intervening at the front end and putting robust privacy protections in place is so important." These could include shielding data from law enforcers and limiting what information is collected and the duration it can be held.

"When we have a technology that holds substantial promise to be put to public benefit, we should make sure that we regulate it appropriately and with public trust and privacy in mind," she says.

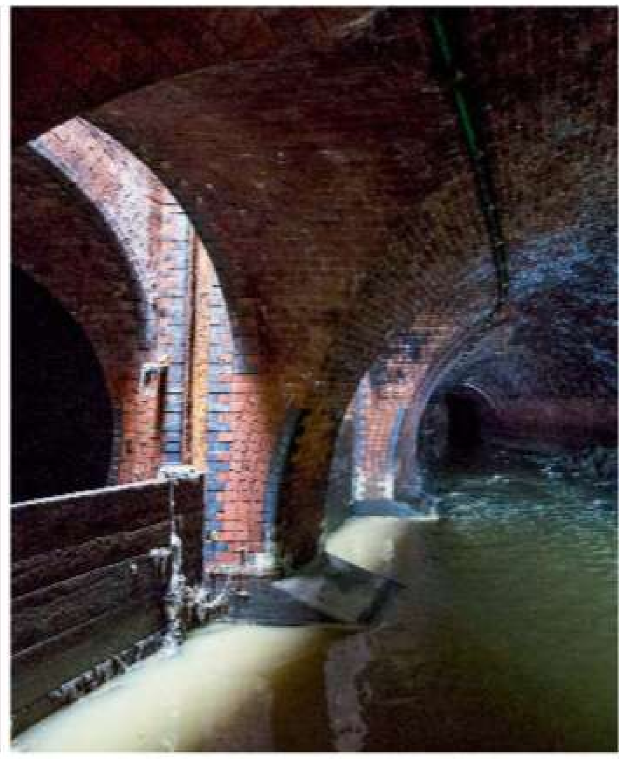
taken a long time to get to the sewage works, many chemicals, especially those related to human metabolism, have broken down by the time they get there. But these ephemeral molecules can be captured further upstream. By sampling from water flowing beneath manholes, scientists can also gain a more detailed picture of what is happening in a particular neighbourhood or even individual buildings. During the pandemic, for example, they used this method to track SARS-CoV-2 infections in nursing homes, hospitals and other places where people crowd together.

Once they have their samples, the researchers separate the sludge from the liquid and the hunt begins. Each chemical of interest has particular qualities like mass and electrical charge, the chemical equivalent of a photofit that scientists can use to pick it out from the crowd with techniques such as mass spectrometry. Meanwhile, another technique, called PCR, can detect specific stretches of genetic material to identify particular viruses, bacteria or antibiotic resistance genes.

But detection is the easy part. "It's not about going in and taking a measurement. It's about developing a platform that can help you reach insights about what's going on," says Alm. One problem is that, along with toilet waste, sewage contains a cocktail of water from showers, washing machines, factory effluents and many other sources. Another is that the amount of a chemical present depends on where the sample was taken and where the people excreting it were located. Also important is how the human body absorbs, processes and excretes a chemical of interest, as well as how and when people consume it.

Alm has helped found a company called Biobot Analytics to get meaningful insights from waste water samples. It uses computer modelling and machine learning to bring together multiple sources of data, such as maps of housing and how many people in the city might be taking a particular illicit drug, to predict where and when in the sewage system it is best to sample. Halden, meanwhile, is CEO of a spin-off company, AquaVitas, which is using similar approaches to help health authorities monitor public health threats.

Such quantified, near-real-time analysis of waste water allows authorities to track things like activity in the illegal drug market. This is already happening in Australia. It can also spot new "designer" drugs, as Richard Bade at the University of South Australia and his colleagues showed in a study that examined



Scientists taking water samples from a manhole in Israel to help them trace the spread of covid-19

CHINE NOUVELLE/SIPA/SHUTTERSTOCK

> "It allows authorities to track things like activity in the illegal drug market"

Waste water in this London sewer contains clues about the behaviour and health of a large number of people

JACK TAYLOR/GETTY IMAGES

SHUTTERSTOCK/AM.P

waste water over New Year 2019-2020. Being able to quantify waste water data is also crucial when studying population exposures to environmental pollutants, to see whether safety thresholds have been crossed, says Barbara Kasprzyk-Hordern at the University of Bath, UK, "You really need to know the numbers."

Take bisphenol A, one of a class of chemicals known as endocrine disruptors that mimic the effect of hormones in the body. There is increasing evidence that these might be partly responsible for the global rise in diabetes and obesity. Kasprzyk-Hordern's team showed that most exposure to bisphenol A – previously believed to come mainly from food packaging – was instead occurring in the workplace. Waste water levels of this chemical were higher on weekdays and lower at the weekend, and higher in catchments with industrial areas than residential ones, probably reflecting occupational exposure.

Health check

Waste water monitoring can also be used to check if public health policies are working, says Kevin Thomas at the University of Queensland, Australia. He and his colleagues studied samples to see what effect a minimum unit price policy had on alcohol consumption in the Northern Territory in Australia. They found consumption dropped by more than a third immediately after the policy came into force in October 2018, but recovered to near pre-policy levels after 15 months, suggesting that additional measures were needed to maintain the reduction.

The team has undertaken similar studies for tobacco. Likewise, Kasprzyk-Hordern and her colleagues have been testing waste water samples in the UK for traces of antibiotics and for bacterial genes conferring antibiotic resistance. This will provide a baseline to test the effectiveness of public health campaigns aimed at tackling the problem of antibiotic resistance by reducing antibiotic use.

Integrating such data with other sources of information can yield even deeper insights. Jake O'Brien at the University of Queensland led a team that correlated Australian census data with a range of biomarkers – chemicals produced by the human body – to investigate the relationship between socio-economics, diet and drug consumption. They found that wealthier, more highly educated communities consumed more citrus, fibre and caffeine, while poorer ones consumed more opioid painkillers, antidepressants and medication for high blood pressure. This suggests that waste water could be used to study the social, economic and demographic determinants of health. In long-term research, it could even track the prevalence of non-communicable conditions such as diabetes and mental health problems.

"There is so much that can be done," says Kasprzyk-Hordern. But there are also challenges. Collecting samples on a large scale is one. Some researchers envision a future where at least some of the sampling and sensing is done automatically by robots in a network of "smart sewers". These might even be linked with each other and other environmental sensing systems via the "internet of things". This remains a distant dream, but Alm's team is currently developing robotic samplers while researchers in Europe have developed a remote-monitoring system for sniffing out illegal drug factories.

Another challenge is protecting the rights of citizens (see "Effluent ethics", left). Politicians objecting to waste water testing for SARS-CoV-2 in North Dakota recently tabled a bill that would ban or restrict such testing for genetic material or evidence of disease, citing concerns over privacy. The bill wasn't passed, but it highlights the importance of public trust in the technology, says Halden. A recent survey of some 3000 adults across the US indicated that most supported waste water surveillance for health monitoring, but with some limitations: people supported its use for applications such as checking for diseases and environmental toxins, but were wary when it came to use related to lifestyle, diet and mental health.

Still, if waste water-based epidemiology can be developed and regulated, it could go a step beyond public acceptance to active public participation. Kasprzyk-Hordern envisages a future where citizens are directly involved, collecting information – about weather or other environmental factors – and adding it to the mix. Waste water epidemiologists are fond of quoting the author Victor Hugo, who described the Parisian sewers as "the conscience of the city", a place that revealed society's hidden truths. Thanks to science, that conscience is being thoroughly examined. ▮

Claire Ainsworth is a freelance writer based in Southampton, UK

HARRIET LEE-MERRION

Spot the difference

Researchers are painstakingly poring over genomes, with a little help from artificial intelligence, to uncover thousands of new species – discoveries that could be key in the fight to rescue biodiversity, finds **Kate Douglas**

"Bats are the most charismatic species out there," says Bryan Carstens, an evolutionary biologist at The Ohio State University in Columbus. Here is an animal that evolved from the same ancestor as we did and yet most species now fly around, hunting down insects in the dark by shouting at them and listening for echoes. They live for decades, longer than other mammals their size, and they are extremely social.

For Carstens, bats are compelling for another reason, too: there are hundreds of unidentified species hiding in plain sight. By scrutinising the genes of the 1400 types of bats we know of, he and his colleagues have discovered 600 new ones. And these hidden species, which have been mistakenly lumped in with others, are just the tip of the iceberg, because Carstens and his team have identified thousands of missing mammals.

We shouldn't be too surprised. It is estimated that between 90 and 99 per cent of all living species are yet to be identified. It is also becoming apparent that many new species have already been collected, but are languishing unrecognised in museums and other institutes. In other words, our knowledge of life on Earth is pitiful. Yet with ingenuity and hard graft, researchers have found a way to reveal the many species we have missed.

It comes not a moment too soon. Our activities are causing a mass extinction rivalling the one that killed off the dinosaurs, and we urgently need to know what species are out there if we are to have any hope of reversing this destruction of biodiversity.

Cataloguing nature is no mean feat. Taxonomists have described some 2 million species, but they only have a vague idea of the true number out there. "A lot of estimates about how many unknown species there might be are based on back-of-the-envelope calculations," says Carstens. Then there is the issue of how you define a species. "The rule is that there aren't really any rules," he says.

Traditionally, taxonomists based their decisions on morphology: they would look at the physical attributes of organisms to decide whether they belonged together. But evolution tends to be a process of constant, gradual change and there is always variety within a population of organisms, so such judgements are inevitably subjective. In recent years, developments in genetics have led to new ways of distinguishing between species. However, there is no consensus on which approach to take, and many genetic analyses ignore physical and behavioural traits, which are what evolution actually works on.

This year, one study aimed to avoid these pitfalls. Horseshoe bats are a rapidly expanding genus consisting of 106 known species, 18 of which have been identified since 2000. Alice Hughes at the University of Hong Kong and her colleagues examined hundreds of individuals from 11 of these. First, they compared the animals' genes and then scrutinised two traits with evolutionary relevance: vocalisations and nose shape.

"The rule of how you define a species is that there aren't really any rules"

Together, genes and morphology revealed that the 11 species contained 44 potential hidden species – indicating that there are around 40 per cent more Asian horseshoe bat species than we thought.

Such gold-standard studies are extremely laborious and still only give insights into a tiny fragment of biodiversity. What's more, taxonomy lacks resources and people power. So how can we understand the bigger picture?

Enter Carstens and his team. With their usual fieldwork curtailed because of the pandemic, they tried to answer this question. Taking on the whole of nature would be too ambitious for a group of five: Carstens and three of his postgraduate students, Danielle Parsons, Jamin Wieringa and Drew Duckett, along with Tara Pelletier at Radford University in Virginia. Instead, they focused on mammals – but with the aim of creating a new way to explore hidden biodiversity that could be rolled out to other organisms.

Taxonomists have identified around 6500 species of mammal and the team looked at 4310 of these, representing all 27 mammalian orders (a group of related species). "We only included species for which we have solid genetic data," says Parsons, the lead author of the recent paper describing

›

the work. In particular, the researchers needed information about two so-called barcoding genes. These are genes on DNA found in mitochondria, the powerhouses of cells where energy is produced. Barcoding genes have been shown to have very specific variations, says Parsons. The two they analysed are the most widely used to identify new mammal species. Ideally, you would want to look at more genes, she admits, but it is a trade-off. "There's less data, but also less cost and less time."

The researchers tested the barcoding data in two ways. The first involved measuring the genetic distance between pairs of individuals. This entails lining up the sequences of the barcoding genes to see how much they differ. If two entities are more than 5 per cent different from one another, they tend to be considered as different species, says Carstens.

The second method takes a more overtly evolutionary approach. It taps into the idea that, although genetic change tends to happen gradually and constantly within populations, when speciation occurs, many parents are passing novel gene variants to their offspring. This can be seen in the genetic data by looking for lineages, where genetic changes are passed down generations without being lost, and plotting these against their time of occurrence. Gradual genetic change will generate few lineages, but when many lineages cluster, that indicates speciation. Although this approach tends to overestimate speciation, the genetic distance method tends to underestimate it. "So they balance each other," says Parsons.

Combining the two methods, the researchers found more than 2000 potential new species hidden within the genomes they examined. A conservative assessment indicated that one-third of the known species they scrutinised contained one or more hidden species. These were particularly common in three orders: bats, rodents and eulipotyphlans (see "Eu what?!", left). In total, the analysis indicated that about 20 per cent of mammals are yet to be identified.

But that was just the start. Next, the researchers wanted a way to predict where these hidden species might be found – crucial information for taxonomists trying to direct their time and resources most effectively. To do this, a massive amount of data had to be crunched: for each of the known species in the study, information had been collated on 117 traits, including aspects of morphology and life history, along with details of the climate, geography and environment they live in – 33 million facts in total. It wouldn't do to use a regular analysis to look for correlations because there are far too many variables and they may be interacting, says Carstens. Instead, they turned to artificial intelligence.

They used a technique called random forest analysis, similar to the approach employed by Netflix to predict which new programmes to recommend, based on your previous viewing. First, the researchers trained their AI on 80 per cent of the data. Then, they used the remaining 20 per cent to test it. This revealed that hidden species are most likely to be found in mammals with small bodies and large ranges that are living in the seasonal tropics, especially in South-East Asia.

Mammals are among the most studied groups of organisms. If our picture of them is so patchy, what does that tell us about estimates of how many of all species we have discovered so far? "I would guess it's closer to

INAKI RELANZON/NATUREPL.COM

There are probably about 40 per cent more horseshoe bat species than we thought

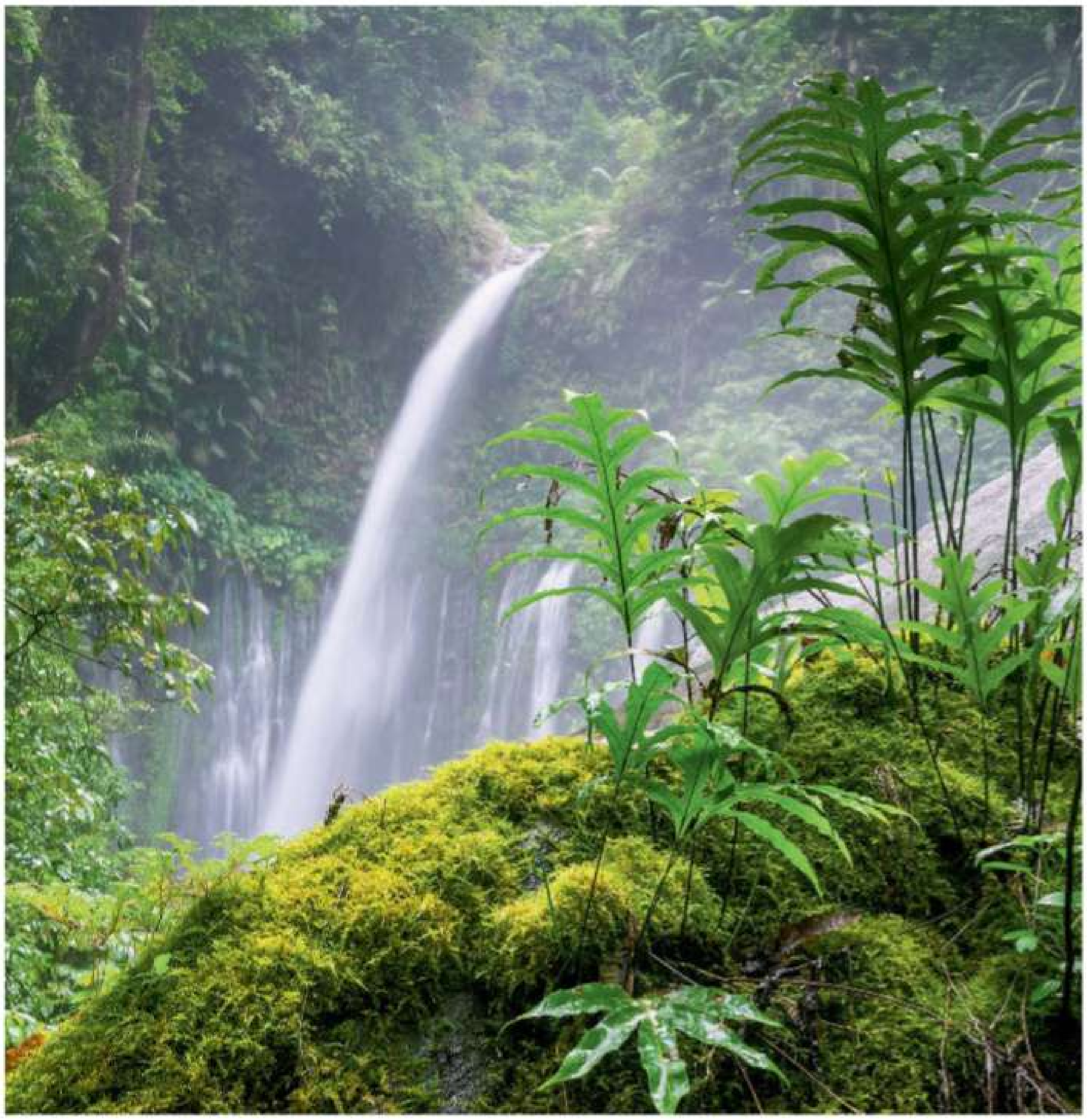
Eu what?!

Eulipotyphla has a satisfying ring when it comes to names for groups of mammals. It translates as "truly fat and blind" and includes a ragtag bunch of hedgehogs, moles, shrews and other pointy-nosed insectivores, so odd that they have only recently been classified as a group. "They used to belong to a waste-bin taxa with all the other things taxonomists didn't really care to identify," says Danielle Parsons at The Ohio State University in Columbus. Nevertheless, to her, they are the most fascinating of mammals. "They're all very interesting," she says. "Some are venomous. They have a lot of weird stuff going on."

Parsons is particularly drawn to shrews. "They're amazing: their hearts beat at 1000 beats per minute, they eat three times their body weight a day, they barely sleep," she says. "North American water shrews are the world's smallest diving mammals and they can do really cool things like smell underwater."

Eulipotyphlans are also one of three mammalian orders that contain the most hidden species. In other words, there are many unidentified new species hidden within the ones described to date, according to genetic analysis by Parsons and her colleagues. "The North American water shrew is being reclassified from a single species to four separate ones," she says. "And there are probably more."

The methods she helped pioneer (see main story) may yet lead to the discovery of new species in all mammal groups, from primates to pangolins, but it is these missing shrews that most excite Parsons. "They're just very charismatic," she says.



SHUTTERSTOCK/IVOHA

A waterfall in Lombok, Indonesia. Rainforests are thought to conceal many unknown species

1 than 10 per cent," says Carstens. "Think about mites. There are mites that live on mites. There are probably mites that live on the mites that live on mites." The researchers believe their method could help predict where missing species are hiding. Admittedly, it can only reveal those lurking within already known specimens. Nevertheless, Carstens suspects there is a correlation with the bigger picture. "This might give a very rough estimate of how many undiscovered species are out there," he says.

Mass extinction

Others are more cautious. One concern is that using genetic analysis to distinguish between species can lead to what is called taxonomic inflation. "Genetic diversity is higher in species with larger populations and high gene flow. So increasing genetic diversity does not mean more species," says Mark Costello at Nord University, Norway. Stephen Garnett at Charles Darwin University, Australia, agrees. "Many taxonomic groups separated on the basis of a few mitochondrial genes do not stand up when examined closely," he says. They both highlight the need to combine genetic analyses with studies of morphology. Even then, there are pitfalls. Hughes, who did just that in her study of horseshoe bats, points out that the most useful distinguishing characteristics may be quite idiosyncratic, like nose-leaf shape, the leaf-like structure on the nose of many bats which had been little studied before now. "If the wrong traits are measured, they will be less useful," she says.

"My biggest issue with many high-volume molecular labs is the lack of morphological analysis and useful characteristics for distinguishing taxonomic groups," says Scott Thomson at the Centre for the Study of Amazon Turtles in Brazil. Nevertheless, he sees the approach developed by Parsons and her colleagues as a "useful tool for focusing research" and encouraging much-needed investment. Hughes says the paper highlights the need for enhanced conservation efforts in critical regions.

> **"The analysis suggests about 20 per cent of mammals are yet to be identified"**

Carstens and Parsons echo this view. "We are waking up to the fact that we have this giant mass extinction going on that we are responsible for. But people are still not fully on board with putting in the effort needed to correct it while we can," says Parsons. "If we're going to make intelligent decisions about conservation and have any hope of saving even a fraction of the biodiversity, we have to know what's out there," adds Carstens.

Their approach could also help with another 21st-century crisis. The covid-19 pandemic has alerted us to the dangers humanity faces from diseases that jump from other animals into humans. As Hughes and her colleagues point out, horseshoe bats are a major source of such pathogens, including coronaviruses like the one that causes covid-19. But they aren't the only ones. To prevent future pandemics, we urgently need to know more about these disease-carrying species.

Ironically, without covid-19 restrictions, Parsons and her colleagues would never have had the time to do this research. "This was an emblematic pandemic science paper," says Carstens. "It's the kind of thing that wouldn't have happened in normal times." ▮

Kate Douglas is a features editor at *New Scientist*

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Humans are weird creatures, with obscure social customs, complex interpersonal relationships and baffling unwritten rules. However, scientist and author Camilla Pang is here to help us understand this strange species.

Diagnosed with autism spectrum disorder at the age of 8, Camilla has created her own manual for understanding humans, which won the Royal Society Insight Investment Science Book Prize in 2020. She is a champion for neurodiversity who recently published a book for children, revealing how as a child she used scientific ideas she understood to help explain social customs she didn't. Camilla believes all children should know it is completely normal to be perfectly weird. In fact, it is essential for growing up happy.

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BEING HUMAN SERIES
CAMILLA PANG

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Science of gardening

Seeds of success

Expand your plant collection for free by saving seeds this year and sowing them next spring, says **Clare Wilson**

Clare Wilson is a reporter at *New Scientist* and writes about everything life-science related Her favourite place is her allotment @ClareWilsonMed

What you need

Paper bags and envelopes
Jars
Plant pots

GROWING your own plants using seeds saved from the previous year has several benefits. It is free, easy and you already know if these plant varieties grow well in your garden.

You can also branch out, if you have been coveting any of your neighbours' flowers, by asking them if they could donate a few flower heads once they have set seed. I have acquired some tall ornamental grasses by taking a few seeds from some striking specimens at my local park.

Bear in mind that some hybrid "F1" varieties of fruits and vegetables shouldn't have their seeds stored. These hybrids have been created by crossing one variety of plant with another, so that their offspring have just the right mix of characteristics. Plants from the next generation, however, will be more variable. Instead, save seeds from varieties that are marketed as heirloom or open-pollinated, the offspring of which should be more similar to their parents.

For flowers and grasses, you may have to watch the plants carefully as their seeds ripen over the summer to make sure you strike at the right time. Too early and the seeds will be immature; too late and the seeds could blow away in the breeze. With fruits, such as tomatoes, just pick them when they seem ripe.

Planting time is usually late winter or very early spring, which means your seeds will need to be dried out so they can be stored for several months without rotting.

GAP PHOTOS/CHRIS BURROWS

Drying options include keeping the seeds in a sealed jar for a week alongside packets of silica gel, which I get by storing the sachets that come with some purchases. Or you can use dehydrated rice, which can be made by drying rice in an oven at 100°C (212°F) for several hours, according to the UK charity Garden Organic. I have previously had success by simply storing flower heads in a large, open paper bag and leaving them in a warm shed for a month.

Tomato seeds are unusual for requiring an extra step: you must first get rid of their surrounding jelly, which contains compounds that inhibit seed germination. Squeeze the seeds and their juice into a jam jar, cover with plastic wrap with a couple of holes in it, and leave to ferment at room temperature for about three days. Then discard the resulting goo – which is, frankly, mouldy and smelly – rinse several times, and dry as for other seeds.

With some plants, such as grasses, you may need to remove any seed casings or husks. Do this by rolling them between your fingers, then get rid of the "chaff" by picking it out, sieving or gently blowing it away, a process known as winnowing.

Once ready, seeds can be kept in paper envelopes in a jar at the back of the fridge over the winter, ready to be sown in small growing trays or pots in early spring. Then the growing cycle can begin again. ▮

Science of gardening appears every four weeks

Next week

Science with children

These articles are posted each week at newscientist.com/maker

OWN YOUR MIND BUSINESS

Discover what makes you tick with How We're Wired, a brand new podcast that looks at what happens inside your brain – from before you were born through to death.

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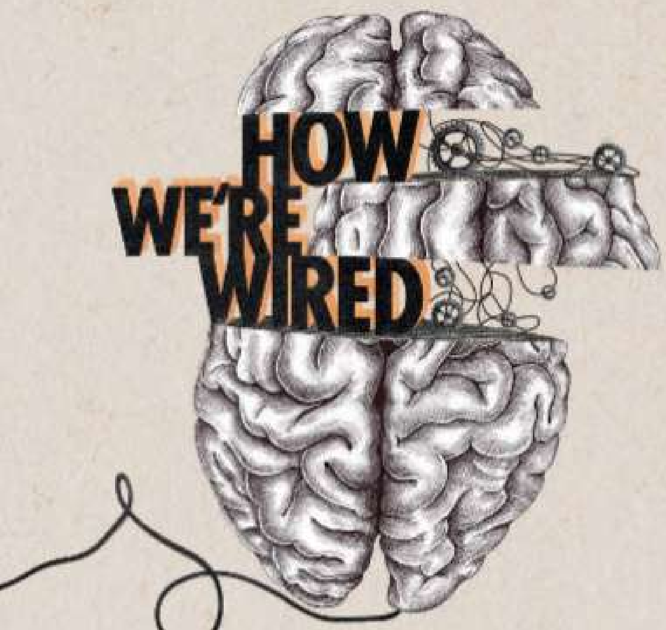

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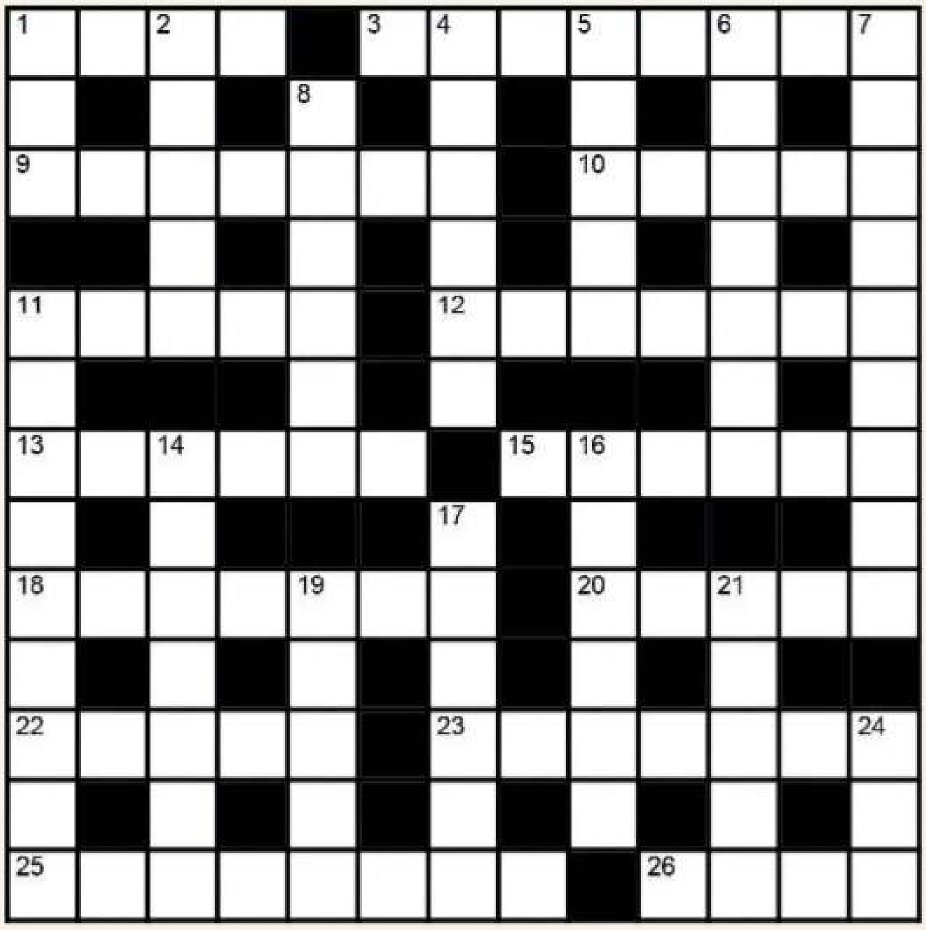
Cryptic crossword #90 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 Bass went the wrong way (4)
3 Arrays table protectors around paella's base (8)
9 Don maintaining place for rubbish online workshop (7)
10 Quaint exclamation at extremely lopsided area surrounding an electromagnet, say (5)
11 Cried out pub order (5)
12 Fuss with second-rate rocket, for instance (3-4)
13 Is collecting stock fantasy character pictures (6)
15 Twist pen, gripping hard (6)
18 Fish darted after irrational chap lacking protection (7)
20 Provided medicine to get rid of green patches from back? (5)
22 Iodine removed from this or that anaesthetic (5)
23 Practise boxing and then fight visitor to garden (7)
25 Wisdom finally prevails with each taking number (8)
26 Jack West dropping electronic instrument that produces 1/10/13 Across (4)

DOWN

1 Condensation expected, we hear (3)
2 Declined place to rest after upsetting play (5)
4 Sudden muscle pressure interrupts routine (6)
5 Once again equip official computer experts (5)
6 Mild adhesive includes bit of lignin (7)
7 Very naughty to flip and scan baked good (4,5)
8 Made up mixture of nut and medicinal evergreen (6)
11 Snip cress, changing textural quality (9)
14 Hindenburg, for one, heading away from bazaars with joint (7)
16 Tyre commercial set in north-facing hideaway (6)
17 Spear travelling at speed of light for astronomical distance (6)
19 Pluck sample from inner vein (5)
21 Yellow skin growths rising (5)
24 With-it comedian (3)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #165

1 A gas giant planet that orbits close to its star is known as a what?

2 Which element was discovered by Bernard Courtois in 1811?

3 In particle physics, what are WIMPs?

4 Sericulture involves the breeding of which creatures?

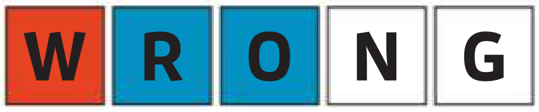
5 The two types of seed-bearing vascular plants are angiosperms and what else?

Answers on page 55

Puzzle

set by Alison Kiddle

#181 A loss for words



Wendy Wordsmith prides herself on her prowess at all the latest online word games. In fact, she hadn't lost a single game since she started playing her latest obsession a couple of months ago. But after being caught out by an alternative spelling, she was dismayed this morning to see her winning streak drop from 100 per cent to precisely 98 per cent.

Since the app rounds percentages to the nearest whole number (9.5 per cent would round up to 10 per cent), how many more games does she need to win without another loss till her game tells her that she is back to 100 per cent?

Solution next week

Wrong odds

Why does an even number feel "right" but an odd one "wrong" when, say, I'm setting my TV volume control? Am I alone in this?

Fleur Hughes
York, UK
You aren't alone. I like the volume set to even numbers or multiples of five, and get really twitchy when these conditions aren't met. I dislike prime numbers especially (I am still a bit funny about the fact that my wedding anniversary is on the 17th day of the month). I think this might be because I am not very good at maths and prefer numbers that are easily divisible.

Somewhere in my hindbrain is a creature that perceives these numbers as collections of small items that need to be put neatly into equal-sized groups.

Gerard Buzolic
Coolum Beach, Queensland, Australia
I feel the same. The reason may be to do with how an even number of anything is divisible into pairs, giving a feeling of balance. An odd number is just a collection of pairs with one left over.

> "I always set my TV volume to a prime number. I also do the same for setting the cruise control when driving"

Lou Everatt-Fletcher
Oxford, UK
I feel exactly the same way. My husband and 10-year-old daughter clearly don't, as they delight in putting the TV volume up to an odd number in order to enjoy my discomfort. They are terrible people!

Geraldine Fenton
Leeds, UK
I used to set the volume to even numbers. My son always used numbers ending in zero or five, so I tried that too. I then decided I was being overly conformist, so, a few years ago, I moved to using prime numbers. They now look perfectly normal to me. My conclusion is that it is just habit.

Peter Dearden
Parkes, New South Wales, Australia
I always set my TV volume to a prime number – I am convinced that, because there are only ever two factors involved, the signal and sound are clearer. I do the same for setting the cruise control when driving.

Sam Edge
Ringwood, Hampshire, UK
I can't say I agree that even numbers feel more "right" than odd. I tend to set volume controls, screen brightnesses, etc to prime numbers. My TV gets reset to 13 every morning, which somehow seems to be the optimal level for background listening. My office monitors are set to 97 per cent screen brightness.

***@Mickytwoshoes65**, via Twitter*
I am obviously a contrarian. I prefer odd numbers, especially prime ones. Even numbers don't do it for me.

***@JezebelImpala**, via Twitter*
I am a strictly odd numbers girl, preferably ones divisible by three. The only even numbers I like are multiples of three. The very best numbers are nine, 21 and 42. Sometimes, I will go wild with a 57 or 72, but not often. I realise that this is barmy, but that is just how I roll.

***@pjjam83**, via Twitter*
I thought I was strange, but it is good to know that there are others out there. I am also annoyed if it isn't a multiple of five.

***@SraVazFranco**, via Twitter*
For me, it feels like the "odd" numbers are on a precipice and I just can't let them hang there.

***@Rebecca89625636**, via Twitter*
It is because even is balanced. But 25 is OK if it is on a 0-100 scale because that is a quarter, which is also correct.

***Adele Burnett**, via Facebook*
It has never occurred to me to think about the number. I just choose the appropriate volume to be able to hear it without being too loud. I wonder if I will think about the number now!

***Mike Wright**, via email*
The number 28 always seems perfect to me.

SHUTTERSTOCK/MURATART

When travelling at the speed of light, would a flashlight illuminate the far wall?

This week's new questions

Speedy light **I am at the rear wall of my spaceship travelling at the speed of light. I switch on my flashlight. Will the light reach the front wall?** ***Tony Woodward**, Portland, Oregon, US*

Taste the sun? **Are fruits and vegetables grown under glass, plastic or artificial light as nutritious as ones grown outside in direct sunlight?** ***Georgina Seaman**, Newbury, Berkshire, UK*

Re-wolfing

Dogs are selectively bred from wolves, so could a Pomeranian, for example, be bred to be like a wolf?

Herman D'Hondt
Mascot, New South Wales, Australia
I can think of two methods to attempt this, though both will only take us part of the way.

First, we could let dogs run wild. As they learn to survive, over the generations, they will lose their domestic traits and revert to being wild animals. However, there is no guarantee the resulting creatures will look like wolves.

This is clear with the dingo, a domesticated dog that reverted to living in the wild thousands of years ago. It doesn't look anything like a wolf. Remember that, due to the unpredictability of mutations, evolution won't run in reverse.

The second method is to breed dogs in captivity. In that case, it is

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Tom Gauld
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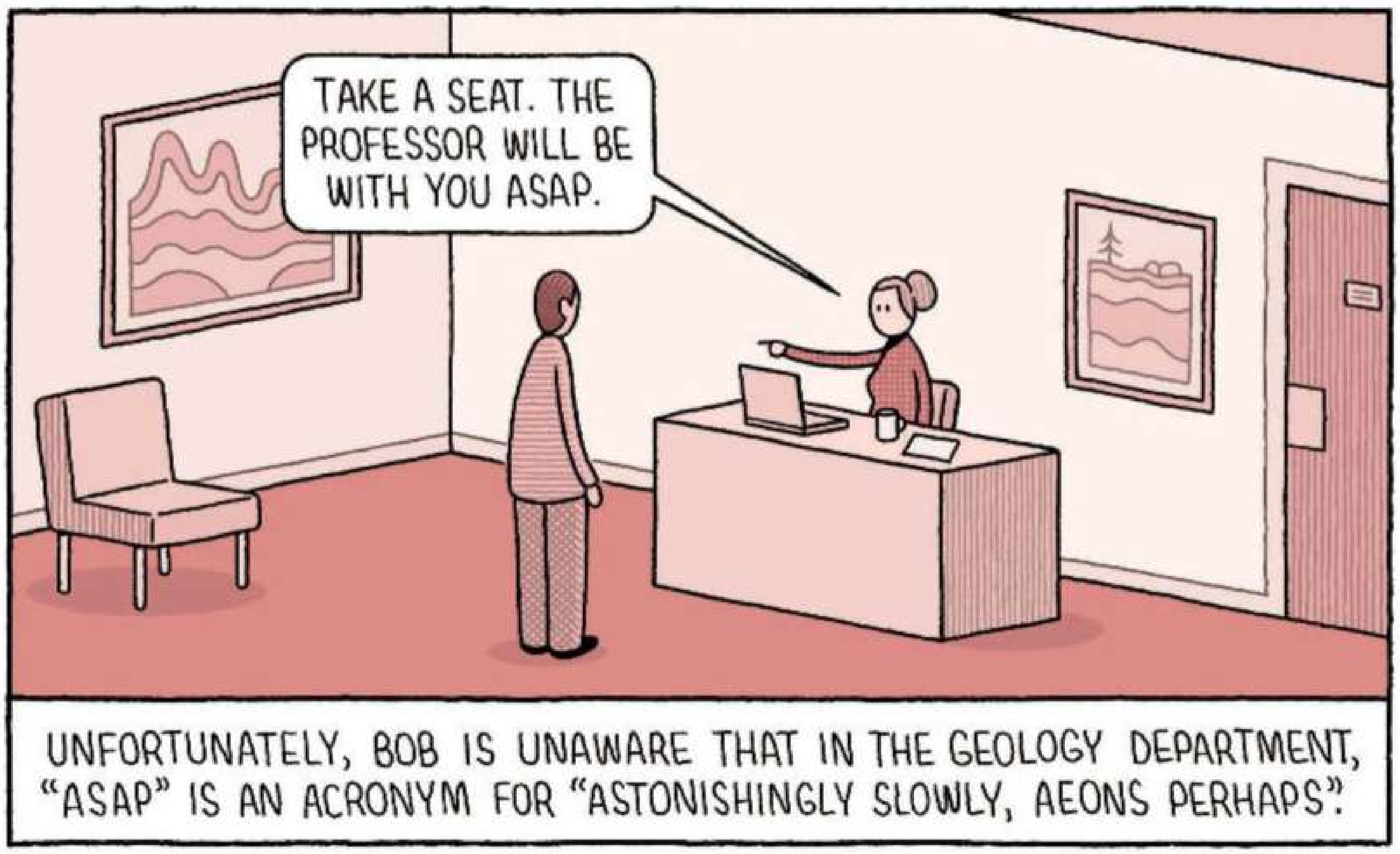
TAKE A SEAT. THE PROFESSOR WILL BE WITH YOU ASAP.
UNFORTUNATELY, BOB IS UNAWARE THAT IN THE GEOLOGY DEPARTMENT, "ASAP" IS AN ACRONYM FOR "ASTONISHINGLY SLOWLY, AEONS PERHAPS".

certainly possible to produce a dog that looks like a wolf.

The German Shepherd already looks quite similar to a wolf and I am sure that similarity could be improved. The problem is that, even looking like a wolf, such an animal would still be a dog in the way it behaves. It would still be friendly to people and wouldn't exhibit the hunting behaviour characteristic of wolves.

To fix that, we could try a reversal of the experiment started by Dmitry Belyaev and Lyudmila Trut at the Institute of Cytology and Genetics in Novosibirsk, Russia, in the 1950s, which aimed to breed tame silver foxes.

To do this, we could select those dogs that exhibit a fear of humans and that like to hunt. This might be a partial solution, but the only way to recreate the pack-hunting behaviour of wolves would be to let the dogs roam free and evolve naturally.

Of course, there would still be no guarantee they would start to hunt like wolves – after thousands of years, dingoes still don't.

> **"If a dog's habitat was changed gradually, then natural selection would push it towards having more wolf-like characteristics"**

Mike Follows
Sutton Coldfield, West Midlands, UK

Dogs and wolves can produce fertile offspring called "wolfdogs". By one definition, this means that they belong to the same species. The dog (*Canis lupus familiaris*) is simply a sub-species of the grey wolf (*Canis lupus*).

Tens of thousands of years ago, it is thought that hungry wolves scavenged on the food our hunter-gatherer ancestors threw away. The aggressive ones were driven out or killed, leaving friendlier wolves closer to our settlements, where they may have warned of predators – and so the process of domestication began.

Given the differences in appearance and behaviour, it is sometimes difficult to believe that all dogs belong to the same species. In fact, all dogs have a virtually identical genome.

In the absence of artificial breeding, there would be less variation amongst dogs, as can be seen among feral street dogs, which are well adapted to their urban environment. If these dogs were dumped into the same habitat as wolves, they probably wouldn't survive. However, if their habitat were changed gradually over many generations, then natural selection is likely to push them towards having more wolf-like characteristics.

However, gene editing may be required because the extreme sociability of dogs has been traced to structural changes in certain genes. Of course, this gene editing is nowhere near as ambitious as the "Chickenosaurus" that palaeontologist Jack Horner wants to produce. Inspired by Michael Crichton's book *Jurassic Park* and the movies that followed, Horner is trying to recreate a dinosaur from a chicken embryo by manipulating various genes. ▮

Answers

Quick quiz #165
Answers

1 A hot Jupiter
2 Iodine
3 Weakly interacting massive particles, a hypothetical dark matter candidate
4 Silkworms, for the production of silk
5 Gymnosperms

Quick crossword #114 *Answers*

ACROSS 1 Velvet, **5** Listeria, **9/18 Down** *The Man in the High [Castle]*, **10** Lethal, **11** Arithmetic, **12** Adds, **13** Opossums, **16** Nailed, **17** At rest, **19** In a flash, **21** Mini, **22** Encryption, **25** Bikini, **26** Seam weld, **27** Phosphor, **28** Europa

DOWN 2 Ether, **3** Vomit, **4** Tinamou, **5** Linctus, **6** Silicon, **7** Estuarial, **8** IP address, **14** Petri dish, **15** Specifics, **19** Incisor, **20** Amylase, **23** Tower, **24** Oxlip

#180 Neat as a PIN
Solution

The PIN is 10256.

Call the five-digit number "N" and the additional added digit and multiple "M". Putting M at the beginning of N makes the number 100,000M + N, and putting M at the end makes it 10N + M.

So M × (10N + M) = 100,000M + N.

Rearranged, this becomes N = M(100,000 – M) ÷ (10M – 1).

If M= 1, then N = 11111, which can't be the PIN as the digits are the same. The only other value of M that makes N a whole number is M=4, with N=10256, and 10256**4** × **4** = **4**10256.

Bounced out of office

A month after Wimbledon, Feedback's summer of sport travels to Central America and a claim that one ancient Mayan ball game required some extremely specialist equipment. As if the capital "I"-shaped court used to play this form of pelota weren't fiendish enough, the ashes of dead rulers were used to make the game's rubber balls.

At least, that is the suggestion made by Juan Yadeun Angulo, an archaeologist at Mexico's National Institute of Anthropology and History. An article in *Science Alert* concludes that Angulo's physical evidence, from a 1300-year-old crypt in Toniná, Mexico, beneath a pyramid called the Temple of the Sun, is still rather sketchy, but there are lots of suggestive carvings and writings to back up the idea.

In the *Popol Vuh* – *the* Maya creation story – the underworld had a ball court in which the game was played with human heads. At the site of the ancient city of Yaxchilán, also in Mexico, meanwhile, there are sculptures showing captives inside rubber balls being chucked about. A figure, resembling Cliff Richard leading rained-off audiences in a singalong, has yet to be assessed.

Power play

Lest we assume the ancients were, in comparison with ourselves, a bit odd, Matteo Lupetti, writing for *VICE Italy*, comes bearing tales of a new video game. *I Am Jesus Christ*, invites us to "perform amazing miracles, interact with a cast of biblical figures and travel around the Holy Land from Jerusalem to the Galilee". The game is still in development, and publisher SimulaM is, appropriately enough, fishing for beta testers.

The cell game

Feedback is already hooked, however, on something else: Excel spreadsheets. A tip from *IFLScience* led us to the high-pressure, high-stakes world of the Financial Modeling World Cup (official slogan, "Excel Esports. Yes. It's a Thing"). Highlights of a recent "all-star battle", featured on CNN, included a yacht race game created entirely in Excel and a reverse-engineering task in which you had to guess the winner of a fictional game from its rules and a list of moves. In future tournaments, extra points may be awarded for working out whose ashes ended up in the ball.

Twisteddoodles *for New Scientist*

The moon Looks amazing tonight
I'll take a quick photo
Do I look small and blurry?
I'll show you
yea, delete that
@twisteddoodles

Got a story for Feedback?
Send it to feedback@newscientist.com or New Scientist, Northcliffe House, 2 Derry Street, London W8 5TT
Consideration of items sent in the post will be delayed

Amazon corner

It seems that you can put whatever you like on a screen and someone will watch it. Entertainment news site *Deadline* reports that MGM Television (owned by Amazon) is developing a wacky, clips-based show hosted by comedian Wanda Sykes and fed by scenes captured by Ring home security cameras (produced by Amazon). With home-footage fame in the offing, perhaps Feedback should invest in a Roomba robo vacuum cleaner (produced by iRobot, which was bought, last Friday, by Amazon).

Hold on, though. Interviewed by *Wired*, privacy advocate Evan Greer pointed out that people think of Amazon as an online retailer, "but really Amazon is a surveillance company", and may therefore have an interest in devices that map and photograph your home.

On the plus side, Feedback (as entrepreneurial as any Amazon exec) can now realise "Dogs vs Roombas" as the mass spectator event it was always meant to be, even while crowdsourcing the hunt for that rubber ball.

Stay alert

Feedback wonders what footage could result from the Ford Motor Company's new idea (US Patent 11396271). It outlines an app to alert pedestrians if an approaching autonomous vehicle isn't going to stop. Vehicle industry newsletter *Jalopnik* points to a possible flaw: "Somehow, asking pedestrians to constantly watch their smartphone to know when a car is headed for the crosswalk seems less than ideal."

Good advice

Such is the zeal among some for self-driving cars, that technology news site *The Verge* has published an impassioned open letter to one enthusiast and reader, headed "Don't do that", and one quickly sees why.

Enraged by what he considers an unfair TV campaign against Tesla's self-driving software, the reader has put out a call for a child to demonstrate the excellence of his car's Autopilot system. "Is there anyone in the Bay Area [of San Francisco] with a child who can run in front of my car on Full Self-Driving Beta to make a point?" he asked Twitter, adding: "I promise I won't run them over."

Er, you just said it is in beta…

Superhuman challenge

Our robot overlords' grip on reality may be getting worse, not better, according to a *Wired* survey of the captcha test hellscape (or "human-computer interaction atrocity" as it has also been dubbed).

One Jared Bauman, for example, founder of a creative marketing agency in San Diego, California, was recently asked to prove his humanity to a web log-in page by saying which of nine pictures contained smiling dogs. "To be honest," he says, "I had a bit of a moment." Eileen Ridge, a tech adviser in Virginia, also admits: "Something about the dogs broke me a little."

Look, you myopic metal minions, we are over here! We are the species that turns its rulers into tennis balls, makes home movies with vacuum cleaners and uses smartphones to cross a road. Do you see us now? ▮

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